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ESG



University of Maribor Press

Jernej Belak

Sunčica Oberman Peterka

editors

Sustainable Governance in the **A**ge of **A**rtificial **I**ntelligence

Interdisciplinary Perspectives on ESG, Digital Transformation and Corporate Responsibility



University of Maribor

Faculty of Economics and Business

Sustainable Governance in the Age of Artificial Intelligence

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Editors

Jernej Belak

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FINANCIAL LITERACY, DIGITAL INCLUSION, AND SUSTAINABLE ECONOMIC GOVERNANCE: COMPARATIVE EVIDENCE FROM THE WESTERN BALKANS

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This study examines the relationship between financial literacy, digital financial inclusion, and sustainable economic governance in the Western Balkans. Using a comparative research design, the analysis integrates data from the S&P Global Financial Literacy Survey, OECD/INFE surveys, PISA 2018, and complementary indicators, alongside macroeconomic variables such as unemployment, GDP trends, and remittances. The findings reveal notable cross-country variation. While financial literacy levels remain relatively similar across the region, digital financial inclusion has expanded significantly between 2011 and 2024, particularly in account ownership and debit card usage. Countries with higher levels of financial inclusion tend to exhibit more favorable economic outcomes, including lower unemployment and reduced reliance on remittances, whereas weaker financial capability and access are associated with greater structural constraints. Persistent challenges include limited participation in credit markets and ongoing gender disparities in access to financial services. The results suggest that financial literacy and digital inclusion operate jointly within a broader economic and institutional context, shaping patterns of economic resilience and development. Strengthening financial capability alongside expanding access to financial services is therefore essential for supporting inclusive and sustainable economic governance in the region.

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1 Introduction

A sustainable economic environment is built upon sound financial conditions and the capacity of individuals to meet present and future financial needs. In this context early financial behaviors and capabilities play a decisive role as they influence not only individual financial security but also broader economic development outcomes. Financial literacy has been widely recognized as a key determinant of economic behavior, shaping savings, investment decisions, and long-term financial well-being (Abdallah et al., 2025; ASIC, 2011; Lusardi & Messy, 2023; Lusardi & Mitchell, 2014; Mitchell & Lusardi, 2021). Empirical evidence indicates that individuals with higher levels of financial literacy are more likely to engage in retirement planning, participate in formal financial systems, and make more prudent borrowing decisions, thereby reducing the risk of excessive indebtedness (Lusardi & Mitchell, 2014; Klapper et al., 2015). At the same time, the rapid digitalization of financial services has fundamentally transformed the way individuals access and use financial products. Digital financial inclusion, defined as access to and usage of formal financial services through digital platforms, has expanded considerably, particularly in emerging and transition economies. However, existing research (Abdallah et al., 2025; Bastidas-Guerrón et al., 2025; Lusardi & Messy, 2023; Zieser et al., 2025) suggests that access alone does not necessarily lead to improved financial outcomes, especially in contexts where digital skills and financial literacy remain limited (Klapper et al., 2015). This highlights the increasing importance of financial literacy as a complementary capability that enables individuals to effectively utilize digital financial services. Despite the growing body of literature, several important gaps remain. First, prior studies (Amnas et al., 2024; Kaiser & Menkhoff, 2017; Zieser et al., 2025) often examine financial literacy and financial inclusion separately, without fully addressing their interaction and joint implications for broader economic outcomes. Second, empirical evidence is largely concentrated in developed economies (Huston, 2010; OECD, 2022, 2023), while research focusing on the Western Balkans remains limited and fragmented. Third, existing studies rarely integrate financial literacy and digital inclusion within a broader framework of sustainable economic governance, including labor market conditions, income dynamics, and reliance on remittances. According to the Organisation for Economic Co-operation and Development (OECD, 2023), financial literacy encompasses knowledge, attitudes, and behaviors; however, its macroeconomic implications are still insufficiently explored. This study addresses these gaps by examining the

relationship between financial literacy, digital financial inclusion, and sustainable economic governance in the Western Balkans. Using a comparative research design, it integrates data on financial literacy, financial inclusion, labor market indicators, income, remittances, and macroeconomic performance across countries in the region. By doing so, the study responds to the need for context-specific evidence that connects individual financial capabilities with broader development outcomes.

The empirical analysis reveals notable regional variation. While financial literacy levels remain relatively close across countries, digital financial inclusion has expanded significantly, particularly through increased use of bank accounts and debit cards. At the same time, the adoption of more advanced financial instruments remains limited, reflecting institutional and economic constraints. Countries such as North Macedonia and Montenegro display relatively stronger alignment across financial inclusion and economic indicators, whereas others continue to face structural challenges related to financial capability, access, and economic integration.

This study contributes to the literature in three main ways. First, it provides empirical evidence from an under-researched region, addressing the geographical imbalance in existing studies. Second, it adopts an integrated analytical framework that captures the interaction between financial literacy and digital financial inclusion. Third, it offers policy-relevant insights by highlighting how these dimensions relate to broader economic conditions, including employment, growth, and structural dependence on remittances. The findings suggest that financial literacy and digital inclusion should be considered complementary components within a broader economic and institutional context. Their interaction shapes not only individual financial behavior but also patterns of economic resilience and development. These insights underscore the importance of coordinated policy approaches, including financial education, inclusive digital strategies, and strengthened institutional frameworks.

2 Literature Review: Financial literacy, Digital Inclusion and Sustainable Economic Governance

Theoretical models assume that individuals have sufficient financial knowledge to plan their savings and spending, but in practice, most do not possess these skills, and acquiring them comes at a cost. This has prompted research and policy to

understand the gaps between theory and reality and to improve existing approaches (Lusardi; Annamaria & Mitchell; Olivia S., 2013; Mitchell & Lusardi, 2021; Ozili; Peterson K, 2025). Financial literacy is generally understood as knowledge of financial concepts and products (Wilson et al., 2014). Historically, financial education has been measured only with questions on basic financial concepts, such as compound interest or inflation, but “literacy” means not only knowing about finances, but understanding and making sound financial decisions, just as the ability to read and write means more than just knowing the letters of the alphabet (Haupt, 2024). The concept of financial literacy dates back to the early 1990s, with Noctor, Stoney and Stradling (1992) considered to be the authors who provided the first widely accepted definition. Their work, cited in later studies such as (Huston, 2010, p. 311), defines financial literacy as “the ability to make informed judgments and make effective decisions regarding the use and management of money”. According to Huston (2010), financial literacy can be conceptualized as a combination of two main dimensions: understanding, which implies personal knowledge about finances, and use, which implies the practical application of this knowledge in personal financial management. Financial literacy today does not only mean theoretical knowledge but also the ability to apply it in practice, where factors such as self-confidence and attitudes towards money are essential for making good financial decisions (Holzmann; Robert, 2010; Kaiser & Menkhoff, 2017).

The literature emphasizes that digital inclusion is not limited to internet access, but also includes digital skills, confidence in the use of technology, and the ability to use digital financial services effectively (OECD, 2021; World Bank, 2022). Numerous studies show that digital inclusion contributes to increasing financial inclusion, reducing transaction costs, and expanding access to formal markets, especially for vulnerable groups such as women, youth, and rural populations. In developing economies, digital inclusion is increasingly seen as a key tool for socio-economic development and reducing structural inequalities (Haupt, 2024; Huston, 2010; Lusardi & Mitchel, 2011).

The concept of sustainable economic governance concerns the ability of institutions to develop policies that support long-term growth, macroeconomic stability and social justice (UNDP, 2020; European Commission, 2021). The literature argues that sustainable governance requires institutional coordination, transparency, inclusive policies, and an orientation towards human capital development (OECD, 2020;

World Bank, 2022). In this context, both financial literacy and digital inclusion, are considered strategic instruments that empower citizens, increase economic participation and strengthen trust in financial and public institutions (OECD, 2021; UNCTAD, 2021). Within this framework, financial literacy and digital inclusion can be understood as key enabling factors that enhance economic participation, strengthen trust in financial and public institutions, and support inclusive growth. Financially literate individuals are more capable of making informed economic decisions, while digitally included populations are better integrated into formal financial systems, jointly contributing to more resilient and sustainable governance structures. Despite these theoretical linkages, the existing literature tends to examine financial literacy, digital inclusion, and sustainable economic governance separately, without adequately capturing their interaction and combined effects. This gap is particularly evident in the context of the Western Balkans, where empirical evidence remains limited and fragmented. Addressing this gap is essential for understanding how micro-level financial capabilities translate into macro-level economic and governance outcomes.

In line with this gap, and consistent with the comparative nature of this study (which does not aim to test causal hypotheses but to analyze relationships across countries), the research is guided by the following questions: (RQ1) How does financial literacy relate to sustainable economic governance in the Western Balkans? (RQ2) What role does digital financial inclusion play in shaping sustainable economic governance? (RQ3) How do financial literacy and digital financial inclusion jointly relate to economic outcomes such as employment, inequality, and reliance on remittances across the region?

3 Data and methodology: Comparative Evidence

This study adopts a comparative research design to examine differences in financial literacy, digital financial inclusion, and related economic indicators across Western Balkan countries. It combines quantitative data with qualitative interpretation, allowing cross-country differences to emerge through relative positioning rather than isolated measures. In line with comparative methodology, the analysis identifies patterns, similarities, and variations across key dimensions, including financial literacy, financial inclusion, and macroeconomic conditions (Bolbakov et al., 2020; Esser & Vliegthart, 2017). Due to limited harmonized national data, the study

integrates multiple international sources to ensure comparability, including the S&P Global Financial Literacy Survey, OECD/INFE surveys (2018–2023), PISA 2018, and complementary indicators from platforms such as OurWealthInsights, alongside macroeconomic data on GDP, unemployment, and remittances. Although differences in measurement exist, their combined use enables a comprehensive assessment of financial capability, financial access, and economic conditions across the region.

To ensure comparability, all indicators were standardized and aggregated into composite measures. Financial literacy was derived from S&P and OECD/INFE scores; financial inclusion from account ownership and debit card usage; economic performance from GDP trends and labor market conditions; and remittance dependence from remittances as a share of GDP. Countries were then classified based on their relative position within the regional distribution (low, medium, high), with intermediate categories used for boundary cases. In addition, a visual representation was developed to integrate these dimensions into a single analytical framework, enabling simultaneous comparison and highlighting patterns of alignment and divergence across countries. This combined tabular and graphical approach supports a more structured interpretation of how financial literacy, digital inclusion, and economic conditions interact.

Table 1: Financial Literacy in Western Balkans

Country	S&P Global (Adults, 2014)*	OECD/INFE (Adults, 2018– 2023)**	PISA 2018 (Students, 15 yrs)***	OtherSources (2022– 2023)****
Albania	38%	53.3 (2019), 59.0 (2023)	-	56%
Bosnia & Her.	35%	63.8 (2022, UNSA study)	-	55%
Norht Macedonia	40%	56.1 (2020, OECD SEE)	-	58%
Montenegr o	44%	54.5 (2020, OECD SEE)	-	57%
Serbia	38%	-	Below OECD average	52%
Kosovo	33%	-	-	50%

Note: * S&P Global Financial Literacy Survey (2014) – percentage of adults answering correctly at least 3 of 4 financial literacy questions. ** OECD/INFE surveys (2018–2023) – values normalized on 0–100 scale, covering knowledge, attitudes, and behavior. *** PISA 2018 Volume IV – 'Are Students Smart About Money?'; Serbia participated, scoring below OECD average in student financial literacy.**** OurWealthInsights (2022–2023) – compiled financial literacy statistics across countries.

Based on Table 1 and data from S&P (2014), OECD/INFE (2020), PISA (2018), and OurWealthInsights (2022–2023), North Macedonia and Montenegro emerge as the strongest performers in financial literacy (OECD/INFE scores: 56.1 and 54.5; S&P Montenegro: 44%; OurWealthInsights: 57–58%), while Kosovo remains the weakest (S&P: 33%; OurWealthInsights: 50%; no OECD/INFE data) and Serbia shows weaknesses among youth (PISA below OECD average), with Albania and Bosnia and Herzegovina positioned at mid-level.

Between 2011 and 2024, financial inclusion improves across all Western Balkan countries, with rising account ownership (A) and strong growth in debit card use (C), while credit card use (B) remains low due to institutional, economic, and cultural factors; although men consistently show higher inclusion, gender gaps narrow by 2024 in Albania, Montenegro, and Serbia, remain wider in Kosovo and Bosnia and Herzegovina, and cross-country differences persist, with North Macedonia and Serbia leading inclusion levels, followed by Montenegro, Albania and Bosnia and Herzegovina progressing more slowly, and Kosovo remaining the lowest performer despite gradual improvement. These differences highlight the uneven development of financial literacy across the Western Balkans and suggest that variations in institutional quality, education systems, and access to financial services may play a significant role in shaping these outcomes. Progress is evident, but achieving inclusive and sustainable outcomes requires parallel improvements in financial literacy, institutional quality, and labor market conditions.

Unemployment rates (Figure 1) declined across the Western Balkans between 2015 and 2024, signaling gradual convergence toward EU labor standards, though disparities persist. Albania fell from 17.19% to 10.25%, Bosnia and Herzegovina from 27.7% to 10.67%, North Macedonia from 26.4% to 13.4%, and Serbia from 17.66% to 7.39%, while Montenegro showed pandemic-related volatility (15.13% in 2019; 17.88% in 2020) before recovery. Kosovo is absent from the harmonized dataset, but national sources (LFS, ASK) consistently report high unemployment, especially among youth and women. The results highlight that labor market performance is a critical component of sustainable economic governance and reinforces the need to complement financial inclusion and literacy policies with broader structural and institutional reforms.

Table 2: Financial Inclusion Indicators by Gender in Western Balkan Countries (2011–2024)

Country	Gender	2011			2014			2017			2021			2024		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Albania	men	34%	13%	26%	43%		26%	42%		30%	43%		26%	51%		35%
Albania	women	23%	8%	16%	34%		18%	38%		24%	46%		28%	41%		31%
Bosnia & H	men	67%	16%	46%	59%		40%	63%		42%	89%	21%	71%	79%	14%	71%
Bosnia & H	women	48%	9%	26%	47%		29%	55%		39%	70%	15%	52%	76%	13%	59%
Kosovo	men	57%		40%	59%	16%	44%	61%	14%	48%	69%	18%	50%	69%	14%	62%
Kosovo	women	31%		18%	36%	11%	24%	44%	7%	27%	47%	7%	31%	60%	8%	49%
Montenegro	men	52%	16%	24%	62%	18%	36%	69%	18%	39%	91%	23%	58%	78%	15%	64%
Montenegro	women	49%	12%	20%	58%	13%	31%	68%	16%	34%	80%	21%	47%	73%	13%	55%
North M	men	76%	17%	39%	80%	26%	62%	80%	19%	58%			68%	92%	28%	81%
North M	women	72%	16%	33%	64%	17%	44%	73%	16%	49%			55%	77%	24%	70%
Serbia	men	62%	22%	42%	83%	15%	59%	73%	19%	64%	89%	17%	26%	86%	25%	78%
Serbia	women	62%	23%	45%	83%	16%	57%	70%	17%	56%	90%	15%	28%	81%	23%	73%

Note: A-Account (%; age 15+); B-Owens a credit card (%; age 15+); C- Owns a debit card (%; age 15+). Source: World Bank. *Global Financial Inclusion Database (Global Findex)*. World Bank Group. <https://www.worldbank.org/en/publication/globalfindex>

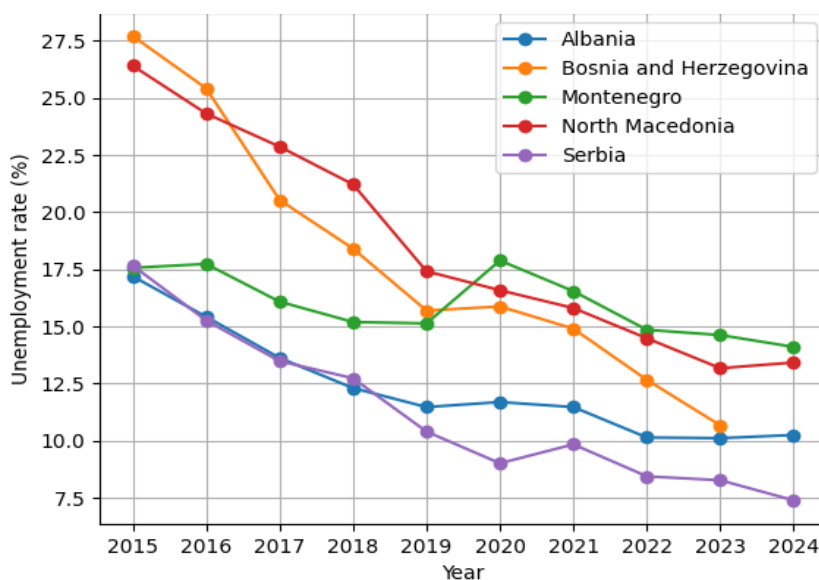


Figure 1. Unemployment, total (% of total labor force) (modeled ILO estimate).

Source of data: World Bank <https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS>, Author's Presentation.

Between 2015 and 2024, economic output increased across all Western Balkan economies despite a temporary pandemic-related decline in 2020, indicating resilient growth supported by investment, exports, services, and gradual EU market alignment. Albania grew from 523.5K to 752.9K, Bosnia and Herzegovina from 8,221.86 to 11,811.94 (with slower progress due to political and administrative constraints), Montenegro recovered from a 2020 tourism-driven contraction to reach 7,212.87 by 2024, and North Macedonia rose steadily from 221.3K to 281.7K driven by FDI and export-oriented manufacturing. Serbia recorded the strongest absolute growth, expanding from 750.1K in 2015 to over 1,105M in 2024, reflecting robust FDI, infrastructure investment, manufacturing, and ICT development with only a mild pandemic shock. Kosovo increased from 2,718.95 to 4,533.21 over the period, supported by remittances, services, and demographic dynamics, although structural unemployment and informality continue to constrain long-term convergence. The results indicate that although all countries are progressing toward higher levels of economic output, significant disparities remain, reflecting differences in economic structure, policy effectiveness, and institutional development. These variations are critical for understanding the broader context of sustainable economic governance in the region.

Remittance data (2014–2024, Figure 2) show large differences across the Western Balkans: Kosovo remains the most dependent (15–18% of GDP), Montenegro and Bosnia and Herzegovina stay above 10%, Albania declines toward ~8%, Serbia remains moderate (6–8%), and North Macedonia the lowest (2–4%), with a clear COVID-related spike in 2020–2021. Overall, remittances help households absorb shocks but also highlight deeper structural issues such as emigration, weak labour markets, and limited economic diversification.

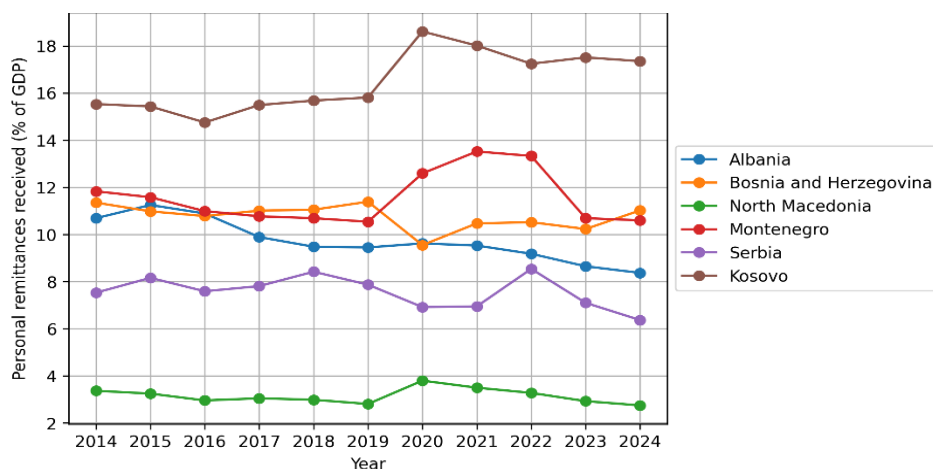


Figure 2. Remittances as Share of GDP in Western Balkans (2014–2024).

Source of data: World Bank, Author's presentation.

Kosovo remains the lowest-wage economy in the Western Balkans, while Montenegro (\$940.63; rank 52) and Serbia (\$876.67; rank 56) lead the region, followed by Bosnia and Herzegovina (\$748.33), Albania (\$712.31), and North Macedonia (\$707.42), with only Ukraine ranking lower in Europe (\$462.17; rank 89) and global contrasts evident with Switzerland (\$7,227), Luxembourg (\$6,314.85), Iceland (\$4,363.18), the USA (\$4,326.26), and Singapore (\$4,023.74). According to ASK (2023), wages in Kosovo increased modestly (gross €521→€570; net €446→€506), driven mainly by public-sector reform (Law No. 08/L-196), while strong sectoral gaps persist between high-paying energy/ICT (€1,039–€974 gross) and low-paying hospitality (€345), confirming that structural segmentation constrains wage convergence.

These results are particularly relevant in the context of sustainable economic governance, as they suggest that while remittances can mitigate economic vulnerabilities, excessive reliance may hinder long-term development by reducing incentives for structural reforms and domestic productivity growth. Therefore, improving financial literacy and financial inclusion becomes critical for channeling remittances toward more productive uses, such as investment and savings, rather than consumption alone.

3.1 Integrated Comparative Analysis: Financial Literacy, Digital Inclusion, and Sustainable Economic Governance in the Western Balkans

This section integrates the empirical findings by situating the observed patterns within a comparative framework across the Western Balkans. When the indicators are considered jointly, financial literacy exhibits relatively limited variation across countries, whereas financial inclusion shows more pronounced differences, particularly in the adoption of basic financial instruments such as account ownership and debit card usage. Countries with higher levels of financial inclusion tend to be associated with more favorable economic conditions, reflected in lower unemployment rates and more stable growth trajectories, as well as lower reliance on remittance inflows.

At the country level, differentiated profiles emerge. Some economies display a more balanced configuration across financial literacy, inclusion, and economic performance, where broader access to financial services is accompanied by stronger labor market outcomes and lower structural dependence on external income sources. In contrast, other cases are characterized by lower financial capability and more limited financial inclusion, combined with weaker economic indicators and higher remittance dependence, suggesting constraints in domestic economic integration. Intermediate patterns are also evident, where improvements in financial access are observable, yet not fully reflected in economic performance, indicating transitional dynamics. Taken together, the findings suggest that financial literacy and digital inclusion evolve within a broader economic and institutional context. Their influence is reflected not only in individual financial behavior but also in aggregate economic outcomes, shaping varying degrees of economic resilience and integration across countries in the region.

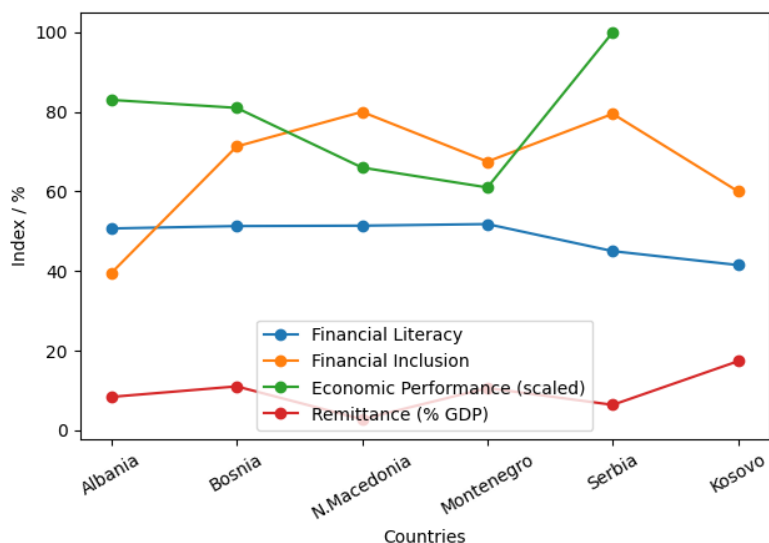


Figure 3. Integrated Relationship between Financial Literacy, Financial Inclusion, and Economic Governance Indicators.

Note: Financial literacy values are derived from Table 1 and represent composite scores calculated as averages of S&P Global Financial Literacy Survey results, OECD/INFE indices, and complementary sources. Financial inclusion values are derived from Table 2 and are calculated using 2024 data as the average of account ownership (A) and debit card usage (C), aggregated across gender. Economic performance is based on unemployment data (Figure 1. unemployment rates), where values are transformed into a relative index (0–100) such that lower unemployment corresponds to higher performance; due to missing data, Kosovo is excluded from this dimension in the figure. Remittance dependence is based on Data on personal remittances received (% of GDP) and is presented in its original form (no transformation), where higher values indicate greater structural dependence. All indices are presented on a comparable scale for visualization purposes.

Figure 3. presents a combined visualization of the key dimensions, allowing for a simultaneous comparison across countries. The figure highlights distinct configurations rather than uniform trends. In some cases, higher financial inclusion is aligned with stronger economic performance and lower remittance dependence, forming a more cohesive structure. In others, financial inclusion improves while economic performance remains moderate and remittance dependence persists, indicating partial alignment. A contrasting pattern is observed where lower financial literacy and inclusion coincide with weaker economic indicators and higher reliance on remittances, reflecting structural vulnerabilities. Across countries, financial inclusion displays greater dispersion compared to financial literacy, which remains relatively stable. Economic performance follows a pattern closer to financial inclusion, while remittance dependence moves in the opposite direction, with higher values indicating greater external reliance. These relationships illustrate that the

interaction between financial capability, access to financial services and macroeconomic conditions operates within a shared structural framework.

Table 3: Integrated Comparative Profile of Western Balkan Countries

Country	Financial Literacy	Financial Inclusion	Economic Performance	Remittance Dependence	Overall Pattern
Albania	Medium	Low	Medium–High	Medium–Low	Transitional structure
Bosnia	Medium–High	Medium–High	Medium–High	Medium	Balanced but moderate
N. Macedonia	Medium–High	High	Medium	Low	More aligned structure
Montenegro	Medium–High	Medium	Medium–Low	Medium	Improving alignment
Serbia	Low–Medium	High	High	Low	Strong internal structure
Kosovo	Low	Medium–Low	Low	High	Structurally constrained

Source: Authors presentation. Note: Classifications are based on composite indicators derived from the underlying data tables. Financial literacy scores are calculated as averages of available indicators from S&P Global, OECD/INFE, and complementary sources. Financial inclusion is measured using 2024 data on account ownership and debit card usage, averaged across gender. Economic performance is assessed through a combined interpretation of GDP growth trends and unemployment levels, where higher growth and lower unemployment indicate stronger performance. Remittance dependence is measured as personal remittances received as a percentage of GDP, where higher values indicate greater structural dependence. Countries are classified based on their relative position within the regional distribution.

The table highlights distinct country profiles across the Western Balkans, where higher financial inclusion and stronger economic performance tend to coincide with lower remittance dependence. In contrast, lower financial literacy and weaker economic conditions are more frequently associated with higher reliance on external income sources, reflecting differing levels of economic integration across the region.

4 Conclusion

This study provides empirical evidence that Western Balkan economies exhibit interconnected patterns across financial literacy, digital inclusion, and broader socio-economic outcomes. The comparative analysis shows that higher levels of financial literacy and financial inclusion are generally associated with more favorable economic indicators, including lower unemployment, stronger growth dynamics, and lower structural dependence on remittances. These relationships are particularly evident in countries where access to financial services is more widespread and more

effectively integrated into economic activity. At the same time, the results reveal persistent disparities across the region. While financial inclusion has improved significantly between 2011 and 2024, especially in terms of account ownership and debit card usage, financial literacy has evolved more slowly and remains relatively uneven. This divergence suggests that expanding access to financial services does not automatically translate into effective usage. Gaps in financial capability, as well as limitations in institutional support, continue to constrain the potential benefits of digital financial inclusion. In addition, credit market participation remains limited and gender disparities persist, indicating that inclusion is still incomplete.

The analysis of macroeconomic indicators further supports these findings. Although GDP has increased across all countries and unemployment has generally declined, the outcomes of economic growth remain unevenly distributed. In particular, the case of Kosovo illustrates how structural constraints—such as high dependence on remittances and weaker labor market conditions—can coexist with economic growth, limiting the extent to which such growth translates into broader development outcomes. While remittances play an important stabilizing role, especially during periods of economic uncertainty, they also reflect underlying structural challenges, including limited domestic opportunities and continued outward migration. Taken together, the findings suggest that financial literacy and digital inclusion should be viewed as complementary components of sustainable economic governance. Their interaction influences not only individual financial behavior but also broader economic resilience, productivity, and institutional effectiveness. Countries that exhibit a more balanced development across these dimensions tend to show stronger economic performance and lower structural vulnerabilities, while weaker alignment is associated with persistent development constraints.

From a policy perspective, the results highlight the importance of advancing financial literacy alongside the expansion of digital financial services. Strengthening financial capability can enhance the effective use of financial systems, support labor market participation, and reduce structural dependence on external income sources. In this sense, financial literacy and digital inclusion should not be treated as isolated policy areas but as integral elements of long-term economic development strategies. Such an approach is essential for fostering inclusive growth, improving economic resilience, and supporting convergence with European development standards.

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Appendix 1. Construction of Composite Indicators

Country	Literacy Score	Inclusion Score	Unemployment (%)	Remittances (% GDP)
Albania	50.7	39.5	10.25	8.37
Bosnia	51.3	71.3	10.67	11.02
N. Macedonia	51.4	80.0	13.42	2.75
Montenegro	51.8	67.5	14.10	10.60
Serbia	45.0	79.5	7.39	6.37
Kosovo	41.5	60.0	n/a	17.35

Note: Composite scores are calculated from the underlying datasets as described in the methodology. Economic performance is interpreted based on GDP trends and unemployment.

DEVELOPING CIRCULAR ECONOMY BUSINESS MODELS – ONE OF THE TOOLS FOR EFFECTIVELY NAVIGATING THE ESG

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Global economic growth and intensifying international competition have led to the excessive consumption of non-renewable resources. The reviewed literature indicates that a primary challenge for effectively navigating ESG criteria is financial reporting - an issue that can be addressed through the adoption of new business models. The author proposes Circular Economy Business Models (CEBMs) as a pivotal tool in this transition. Research presented in this chapter suggests that the establishment of a circular economy (CE) is fundamentally dependent on the implementation of these models. By adopting CEBMs, individuals undergo a shift in behaviour, business vision, and values, impacting both their professional lives and their wider social and domestic environments. The author examines this issue through a systemic lens, clarifying complex interconnections. This is supported by two graphical representations: the first illustrates the links between CEBMs and ESG pillars, while the second explores the relationship between individual behavioural change and a proactive ESG-navigating attitude.

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1 Introduction

The growth of the world economy and the strengthening of international competition has led to the excessive use of non-renewable resources. Scientists have warned against this process since the last century, and the issue of the need for sustainable development has become one of the foremost challenges of the age. ESG investing has its roots in the “socially responsible investing” movement that was born in the 1970s and 1980s (Clahane, 2024). Subsequently, achieving sustainability and resilience became the goal for which numerous international agreements and documents have been adopted, especially in Europe (European Commission, 2020a; 2019a; 2019b). “There is only one planet Earth, yet by 2050, the world will be consuming as if there were three. Global consumption of materials such as biomass, fossil fuels, metals and minerals is expected to double in the next forty years, while annual waste generation is projected to increase by 70% by 2050” (COM, 2020b, 98 final, p. 2). “Sustainability and the transition to a safe, climate-neutral, climate-resilient, more resource-efficient and circular economy are crucial to ensuring the long-term competitiveness of the Union economy. Sustainability has long been central to the Union project, and the Treaty on European Union and the Treaty on the Functioning of the European Union (TFEU) reflect its social and environmental dimensions” (Regulation, EU, 2020/852, p.1). Achieving a climate-neutral and circular economy without diffuse pollution requires the full mobilisation of all economic sectors (Directive, EU, 2022/2464). According to the Regulation of the EU Parliament (SEC, 2022, 165 final), “by applying the Ecodesign approach to a very broad range of products and enabling it to set a wide range of targeted product requirements, this regulation seeks to address the most detrimental environmental impacts of products. It therefore lays down a framework for setting ecodesign requirements based on the sustainability and circularity aspects listed in the Circular Economy Action Plan” (p.2).

This chapter provides a literature review on ESG navigation challenges. It includes both a description of general difficulties and an introduction to the experiences of different countries. The review of the relevant literature continues with a discussion of the circular economy (CE) and its business models. Here, their special importance in overcoming the challenges of extending resource use and minimizing waste is highlighted. The author further develops the idea that the introduction of circular economy business models (CEBMs) will lead to overcoming ESG navigation

challenges, and offers a systemic depiction of this process. This is supported by two graphical representations: the first illustrates the links between CEBMs and ESG pillars, while the second explores the relationship between individual behavioural change and a proactive ESG-navigating attitude. The chapter ends with brief conclusions.

2 Literature review

2.1 ESG navigation challenges – a brief literature review

This section reviews the extant literature across three primary domains: ESG criteria, the CE, and CEBMs (encompassing both theoretical frameworks and international case studies). The objective is to identify shared challenges inherent across these fields. To address these commonalities, the subsequent section proposes a systemic approach, supported by two original graphical representations.

Over the last few decades companies' performance has come under scrutiny, not just for financial returns, but also for their impact on the environment, social welfare, and governance practices (Healy et al., 2026; Casalegno et al., 2024; Gagnidze, 2024a; Clark et al., 2015). There are a variety of approaches to identifying ESG navigation challenges. Githui, & Njuru (2026) link the ESG framework to a company's competitiveness. The OECD (2025) has developed a number of metrics across the E, S, and G categories. Bernard et al., (2025), revealed clear variations in ESG priorities across hospitality subsectors. Andréason & Miskolczi (2024) examining the relationship between ESG and bankruptcy risk for European manufacturers. Treepongkaruna et al., (2024) show the influence the size of a corporate board has on firms' ESG controversies. Their analysis suggests that businesses with larger boards are more effective in mitigating ESG controversies. Specifically, a rise in board size by one standard deviation results in a decline in ESG controversies by 4.30%. Larger boards, with more human capital and more interactions with stakeholders, promote sustainability more effectively.

Dong (2023) stresses the need for senior leadership support, establishment a systematic framework, and effective communication with stakeholders for successful ESG strategy implementation. Veeramani et al., (2023) argue ESG impact types and present a comprehensive system leveraging ensemble learning techniques,

capitalizing on early and late fusion approaches. Their system offers a comprehensive ESG impact type identification solution, contributing to the responsible and sustainable decision-making processes vital in today's financial and corporate governance landscape. Liu et al., (2023) explore the construction of a reliable ESG scoring engine, with a focus on the importance of data sources and quality, selection of ESG indicators, weighting and aggregation methodologies, and the necessary validation and benchmarking procedures. Different data types, namely self-reported data, third-party data, and alternative data, are critically evaluated for their respective merits and limitations.

McKinsey&Company identifies The five links, which are a way to think of ESG systematically, namely: *Top-line growth* (When governing authorities trust corporate actors, they are more likely to award them the access, approvals, and licenses that afford fresh opportunities for growth), *Cost reductions* (Among other advantages, executing ESG effectively can help combat rising operating expenses (such as raw-material costs and the true cost of water or carbon), which McKinsey research has found can affect operating profits by as much as 60 percent), *Regulatory and legal interventions* (A stronger external-value proposition can enable companies to achieve greater strategic freedom, easing regulatory pressure), *Productivity uplift* (A strong ESG proposition can help companies attract and retain quality employees, enhance employee motivation by instilling a sense of purpose, and increase productivity overall) and *Investment and asset optimization* (A strong ESG proposition can enhance investment returns by allocating capital to more promising and more sustainable opportunities (for example, renewables, waste reduction, and scrubbers) (McKinsey&Company, 2019, pp.4-7).

It is important to learn about the experiences of individual countries in navigating the ESG. Strouhal et al., (2025) explore stakeholder perceptions of ESG reporting in *Czechia* and *Estonia*, two EU member states with differing corporate governance traditions, to identify key drivers, challenges, and the alignment of ESG disclosure with stakeholder expectations in transitional economies. Effective ESG transition in Czechia and Estonia requires coordinated efforts, including government support for SMEs, clear regulatory guidance, industry knowledge-sharing, and responsible financial sector engagement to navigate complexities and realize potential benefits. Del Sarto (2025) examines the impact of ESG controversies on bank risk, focusing on the moderating role of corporate governance. Using a dynamic panel dataset of

88 European banks from 2013 to 2020, we analyze two key risk measures: the Z-score, indicating financial stability, and risk-weighted assets (RWAs), reflecting risk exposure. The findings reveal that banks facing ESG controversies are exposed to heightened risk, with corporate governance playing a crucial role in moderating these effects.

Fodouop Kouam (2025) uses a quantitative research paradigm to analyze data from a sample of 250 companies (from *Brazil, India, South Africa, Mexico, Vietnam, Indonesia, Nigeria, Malaysia, Thailand*, etc.) across diverse sectors, including finance, manufacturing, energy, and technology. According to the authors, significant barriers to effective ESG integration include weak regulatory frameworks, cultural resistance, and a lack of high-quality ESG data. Samsudin et al., (2025) argue that ESG controversies reflect the responsibility to which corporate social responsibility (CSR) committees within firms act with genuine intentions. With the continuous development of ESG practices and the increasing number of environmental and social controversies in the *Malaysian* corporate environment, this study examines whether ESG controversies (ESGCON) influence the relationship between CSR committees and ESG performance among publicly listed firms in Malaysia. Sari et al., (2025) examine the influence of corporate governance and ESG disclosure on firm value in publicly listed companies in *Indonesia*. The analysis indicates that board independence and ESG disclosure have a significant positive impact on firm value, while board size shows a negative but insignificant effect. These findings suggest that strong governance structures and transparent ESG practices contribute to market-based performance and investor confidence.

Keegan (2024) reveals a significant relationship between Greenhouse Gases (GHG) emissions and financial performance, indicating that reduced emissions are often associated with increased revenue in the *USA*. The study also finds that the Sustainability Accounting Standards Board (SASB - is a voluntary reporting framework that provides guidance for 77 industries. These standards are guidelines to companies for reporting on ESG matters that have a material financial impact on business, governmental and nonprofit entities) and GHG Protocol are the most widely adopted frameworks, reflecting a trend towards greater transparency and accountability in sustainability reporting. Utilizing quantitative methods, Elamer & Boulhaga (2024) analyze data from 5360 firm-year observations. Their findings reveal a significant negative relation between ESG controversies and firm

performance. However, well-defined corporate governance frameworks and internal ESG strategies mitigate these adverse impacts and can transform these controversies into growth opportunities and reputation enhancement. A comparative analysis involving *the United Kingdom* and other European Union nations highlights the influence of geographical and regulatory contexts in shaping this dynamic. Xu et al., (2024) investigate the relationship between ESG performance and corporate resilience utilizing data from *Chinese*-listed companies from 2010 to 2022. The study finds a positive and statistically significant relationship between corporate resilience and ESG performance, thereby providing new evidence of the influence of ESG performance on corporate resilience. Biswas et al., (2024) outline that CSR in *India* primarily focuses on monetary contributions to social causes but overlooks corporate externalities. This underscores the growing importance of ESG, reflecting global trends towards market-driven practices and regulatory interventions. In essence, the transition from CSR to ESG in India is a call to strategic leadership, collaboration, and an unwavering commitment to continuous improvement.

2.2 Formation of CE through the development of CEBMs

The Circular Economy Action Plan underlines that, ‘for citizens, the CE will provide high-quality, functional and safe products which are efficient and affordable, last longer and are designed for reuse, repair, and high-quality recycling’ (Regulation, EU, 2024/1781, p.1). ‘CE’ means an economic system whereby the value of products, materials and other resources in the economy is maintained for as long as possible, enhancing their efficient use in production and consumption, thereby reducing the environmental impact of their use, minimising waste and the release of hazardous substances at all stages of their life cycle, including through the application of the waste hierarchy” (Regulation, EU, 2020/852, p. 13). There are also 12 main and 2 additional sub-points that describe in detail the activities that contribute to the transition to a CE. In our opinion, these activities should be implemented through the implementation of CEBMs. One study estimates that applying CE principles across the EU economy has the potential to increase EU GDP by an additional 0.5% by 2030 creating around 700 000 new jobs (Cambridge Econometrics, 2018).

Many researchers are examining the circular economy and its business models from different perspectives. Rumasukun (2026) examines the integration of CE principles into supply chain management (SCM) as a strategic response to Sustainable Development Goal 12 (SDG 12) on responsible consumption and production. Using a qualitative literature-based approach, the research synthesizes recent theoretical advancements and empirical evidence to explore how CE reshapes supply chain structures, operational processes, and sustainability outcomes across global industries. Crammond et al., (2026) explore how Artificial Intelligence (AI) serves as a critical enabler for transitioning from linear to circular business models and ecosystems. Chaudhary et al., (2025) explain how digital capabilities assist in developing organizational capabilities in the form of pollution control, stewardship, sustainability, and regeneration strategies.

Engzell and Kambanou (2024) discuss: “Classic long-life; Hybrid; Access; Performance; Encourage efficiency; Gap exploiter or extending product value; Extending resource; Value and Industrial symbiosis CEBMs” (p. 555). Tuzemen and Kunday (2023) categorised circular start-ups under five categories: 1) Recycling Companies, 2) Sharing Based Endeavors, 3) Recycled Material Users, 4) Second-Hand Product Marketplaces, 5) Waste Management Platforms. According Winquist et al., (2023) “the R-strategies can be classified under three approaches: 1) smarter product use and manufacture (R0 Refuse, R1 Rethink, R2Reduce), 2) Life extension strategies (R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Re-purpose), and 3) creative material application (R8 Recycle, R9 Recover) (p. 3). Henry et al., (2020) have given five circular start -up archetypes: design-based, waste-based, platform-based, servicebased and nature-based start-ups. The OECD (2019) identifies “five CEBMs: Circular supply models; Resource recovery models; Product life extension models; Sharing models and Product Service System Models” (p.4).

Critical perspectives on the CE and CEBMs are also well-documented within the scientific literature. Marjanović et al., (2026) critically examine the role of the circular economy in urban and regional governance, focusing on its social and political dimensions, often overlooked in favour of technical and economic considerations. Corvellec et al. (2022) criticise the concept of the circular economy, arguing that it possesses diffuse boundaries and unclear theoretical foundations, and that its implementation faces significant structural obstacles. They contend that the circular economy is built upon an ideological agenda dominated by technical and economic

perspectives; consequently, it offers uncertain contributions to sustainability and serves to depoliticise the discourse surrounding sustainable growth.

Thus, despite the many forms of CEBMs mentioned above, they all have in common that their goal is to extend the viability of resources while producing minimal waste.

3 How does the implementation of CEBMs contribute to Navigating the ESG? - A Systemic Approach

“ESG” concerns are driving businesses globally to rethink, re-calibrate and sometimes even re-invent their business models, including merger and acquisition (M&A) transactions (Afsharipour, 2023). According to the Cambridge Econometrics (2018) sectors that produce and process raw materials will decline in size while the recycling and repair sectors will experience additional growth (p. 6). From all of the above, it can be seen that the introduction of CEBMs stimulates the formation of CE, which is in the interest of the rational development of the world economy.

The impact of the introduction of the CE and its business models on sustainability is discussed with a systemic approach by Dominici and Gagnidze (2025). They present the systems, where each of the, above mentioned, five CEBMs simultaneously affects the process of achieving sustainability (at the macro and micro levels). These models address environmental concerns by reducing waste and emissions, promoting economic growth through resource efficiency, and enhancing social well-being by creating healthier living environments and improving job prospects (pp. 203-205). By developing hypotheses based on theoretical and graphical representations Gagnidze (2024b) demonstrates the potential benefits of integrating circular sustainable principles into business practices.

This time, the impact of CEBMs on the effective navigation of ESG will be presented using a systemic approach. In general, a schematic representation of any process always reflects reality in a simplified way, therefore, the detailed models of CEBMs discussed above will not be taken into account. When building the system, 5 “Re-“models will be used: “REduce, REuse, REmake, REcover, RENew” (Shields, 2019, p. 2). It can be seen from Figure 1, that the implementation of these models

will directly affect two directions of ESG (Environmental and Social). Together, they will, in turn, affect the third direction, namely “Governance”.

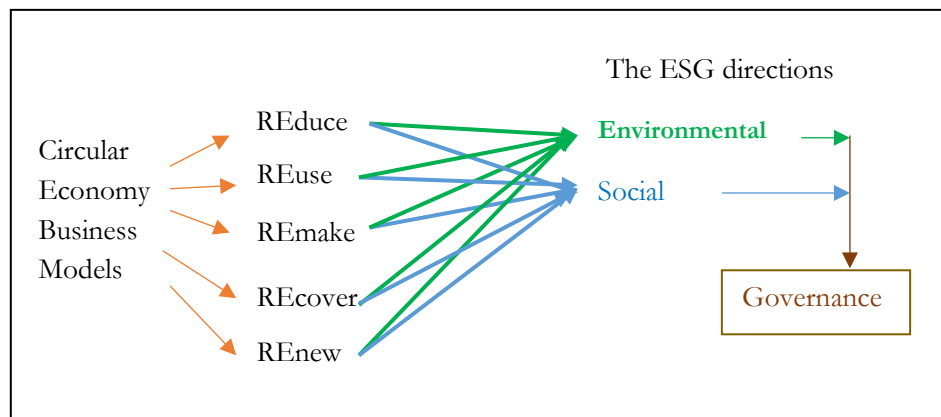


Figure 1: Interconnections between CEBMs and the ESG directions
(Source: own).

It is worth noting that in order to effectively implement CEBMs, individuals need to be prepared for change (Salazar et al., 2023). They need to change their lifestyle (reduce waste, recycle, renew, etc.), their choices for themselves and others (e.g., purchase items made with CEBMs and gift(s) for others) (see Figure 2).

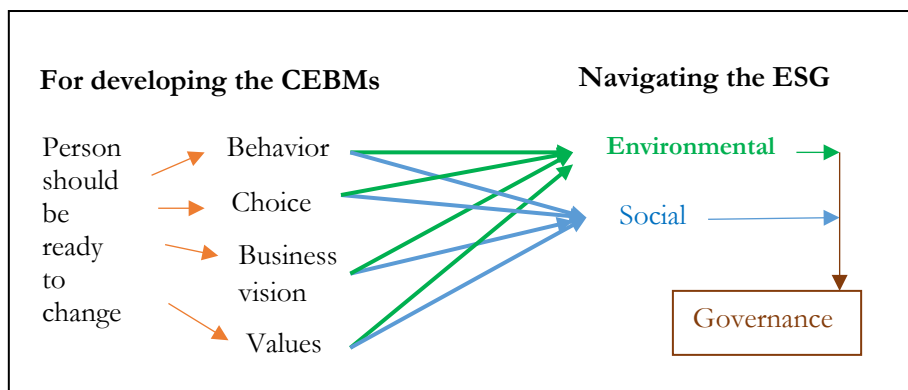


Figure 2: Individual behavioral change and the ESG navigating attitude
(Source: own).

The introduction of a CEMBs and such a vision of business stimulates the rational behavior of individuals not only in families, but also in workplaces (whether in their own business or as an employee in such a business), which forms values, and this attitude becomes contagious to others. As can be seen from Figure 2, the introduction of CEBMs will directly affect two directions of ESG, which in unity will affect the third direction. It is worth noting that with such an attitude, management becomes much easier.

4 Conclusions

Today, companies of every size are judged not just by what they produce, but by how responsibly they operate. ESG reporting integrates these principles into core strategies; driving innovation, trust, and long-term results. Thus, ESG reporting has evolved from a niche corporate trend into a business imperative (ESG Report, 2025). The analysis of the literature presented in the chapter confirms that the intensive and irrational use of non-renewable resources already became apparent in the last century. Many regulations have been developed in an attempt to counteract this process. Calls for sustainable development have been replaced by the development of measures for the effective management of sustainability and ESG, and the development of plans for the formation of a CE. In countries moving in this direction, different types of challenges have been identified. The chapter suggests the possibility of systemic development in the effective management of ESG through the development of CEBMs. This is illustrated by two systems developed by the author. The systems presented in this chapter demonstrate that if policymakers can design effective incentives (such as promoting products from CEBMs by highlighting their environmental benefits, including them in product bundles, or offering various promotions) and regulations (for example, waste-reduction taxes, mandatory waste separation, and the use of reusable items), then ESG navigation will be significantly more straightforward.

The chapter is conceptual in nature (it advances theoretical understanding by synthesizing existing literature to propose new models, rather than presenting new empirical data) and is limited by the lack of practical research, which the author will conduct in the future. There is significant scope for deploying the systemic approach proposed herein to facilitate the transition towards CEMBs within individual industrial sectors.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN THE SUSTAINABILITY OF MARKETING ACTIVITIES: CONTROL OF DIGITAL MARKETING ACTIVITIES AND DIGITAL ANALYTICS

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The control of digital marketing activities plays a central role in strategic management, ensuring the alignment of marketing initiatives with organizational objectives and long-term sustainability goals. In recent years, digital marketing control has increasingly been operationalized through advanced digital analytics tools, which are further enhanced by artificial intelligence (AI) technologies. The integration of AI enables more accurate monitoring and evaluation of marketing campaign performance, supports advanced levels of personalization, and facilitates real-time, data-driven decision-making, thereby improving both operational efficiency and strategic effectiveness. Despite the growing body of research on digital marketing analytics and AI applications, there remains a limited understanding of how AI-based tools specifically contribute to the control function of digital marketing and how these contributions translate into sustainability and competitive performance outcomes. This paper adopts a descriptive-analytical research approach, drawing on a comprehensive review of relevant academic and professional literature in the fields of digital marketing, digital analytics, marketing control, and AI. Furthermore, the study employs a case study analysis based on multiple approach of selected companies that apply AI-based tools in the control of digital marketing activities.

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1 Introduction

The use of artificial intelligence (AI) in digital marketing increasingly contributes to the reduction of resource waste and the advancement of sustainable business practices encompassing economic, environmental, and social dimensions (Gündüzyeli, 2024). AI can be applied in marketing research, segmentation, targeting, positioning, and operational activities based on different levels of artificial intelligence, including mechanical AI, thinking AI, and feeling AI (Huang et al., 2021).

At the same time, AI is redefining contemporary marketing strategies within digital environments, enabling more advanced forms of analytics and decision-making processes (van Esch & Stewart Black, 2019).

In this context, the application of AI in digital marketing can be understood through two complementary perspectives: as a tool that supports sustainable marketing and business activities, and as a technology that promotes sustainable development and environmental responsibility.

The aim of this paper is to examine the role of artificial intelligence in digital marketing through the lens of sustainability, with particular emphasis on personalization, ethics, and transparency. By analyzing contemporary academic studies and practical marketing campaigns, the paper demonstrates how the integration of AI technologies and sustainability principles is transforming the way brands communicate with consumers and shape their marketing strategies in the digital era.

2 Literature review

The literature addresses key themes related to the role of AI in digital marketing, including sustainability, personalization, marketing analytics and control, ethical considerations, consumer trust, eco-friendly marketing practices, and the need for a more integrated and system-oriented scientific development of the field.

The use of AI in digital marketing campaigns contributes to the reduction of resource waste, and sustainable practices are analyzed from the perspective of their contribution to marketing sustainability as well as to economic, environmental, and social objectives (Gündüzyeli, 2024). AI is redefining marketing strategies within the digital environment (van Esch & Stewart Black, 2019).

Accordingly, the application of AI in digital marketing activities can be analyzed through two integrated approaches: the contribution of AI to sustainable marketing and business activities, and AI as a tool for promoting sustainable development and environmental responsibility.

The contribution of AI to sustainable marketing and business activities is reflected in the use of AI to identify customer preferences and to enable product delivery without explicit ordering (Agrawal et al., 2018), as well as in the deployment of AI agents to enhance salesforce capabilities (Davenport et al., 2020). The study by Aljumah et al. (2025) examines sustainable digital marketing behavior among employees that supports sustainable marketing practices. The application of AI in marketing also encompasses the examination of personalization, analytics, ethics, and consumer trust (Mustak et al., 2021).

Responsible and sustainable digital marketing practices contribute to trust in AI and lead to positive purchasing outcomes (Alsaffarini & Awwad, 2026).

The literature review, also, includes studies that analyze the relationship between AI and the management, control, and optimization of digital marketing activities. Digital analytics influences activity control and business sustainability (Wamba et al., 2017) and reshapes the management of marketing processes (Erevelles et al., 2016). Big data analytics transforms the management of the entire marketing process (Erevelles et al., 2016). Key AI technologies in marketing include machine learning, chatbots, recommendation algorithms, and big data analytics (Kumar et al., 2019). The study by Wedel and Kannan (2016) indicates that marketing analytics encompasses analytics for optimizing investments in the marketing mix within big data environments, analytics for personalization, and analytics in the context of user privacy and data security (Wedel & Kannan, 2016).

On the other hand, AI contributes to the personalization of environmentally conscious content by aligning marketing activities with responsible environmental practices (Acatrinei et al., 2025), which in turn shapes consumer perceptions toward environmentally friendly brands (Garg et al., 2025). In this context, the literature addresses the issue of sustainable and responsible AI-driven marketing (Le, 2025), where sustainable marketing directs economic strategies toward balancing economic objectives with the preservation of natural resources (Hollensen et al., 2017). AI is also employed as a tool for eco-branding and the creation of content aligned with environmental values by well-known brands such as Unilever and IKEA (Green City Times, n.d.).

The further development and application of AI in digital marketing will be closely linked to the ethical use of AI, as ethical AI practices influence socially responsible and sustainable marketing outcomes (Zeng et al., 2021). Moreover, the adoption of AI in marketing activities depends on trust and ethical implementation, which are critical for sustainability in digital marketing (Puntoni et al., 2021). In addition, studies also highlight the need for the scientific development of marketing based on a structure–system approach aims to foster scientific convergence and integration (Golinelli et al., 2012) and to reduce the influence of a strong reductionist perspective, which is primarily focused on individual actors and transactions (Tronvoll et al., 2017).

The literature review indicates a limited number of empirical studies that quantify how AI in digital marketing influences companies' actual sustainable performance outcomes.

The aim of this paper is to examine the role of artificial intelligence in digital marketing through the lens of sustainability, with a particular focus on personalization, ethics, and transparency. By analyzing current academic studies and practical marketing campaigns, the paper demonstrates how the integration of AI tools and sustainable principles is transforming the way brands communicate with consumers and shape their marketing strategies in the digital era.

3 Methodology

Based on the literature that highlights the key principles of AI-driven marketing and sustainable practices (Hollensen, Kotler, & Opresnik, 2017; Puntoni et al., 2021; van Esch & Stewart Black, 2019), as well as the importance of controlling digital activities and ensuring transparency (Martin & Murphy, 2017; Zeng et al., 2021), this paper employs case studies to examine how theoretical recommendations are translated into practical marketing campaigns that combine personalization, consumer engagement, and environmental responsibility. The literature indicates that, while there is a substantial body of theoretical and quantitative research on AI in marketing, there is a relative lack of in-depth analyses focusing on the implementation of AI in sustainable marketing campaigns.

The study adopts a qualitative approach to investigate the role of AI in sustainable digital marketing through the analysis of case studies of leading global brands: Nike, Starbucks, and Nestlé.

The analysis is based on the use of both primary and secondary data sources, including official company reports, marketing campaign reports and promotional materials, as well as academic articles and publications that examine the application of AI in digital marketing.

The study employs a thematic analysis based on a hybrid coding strategy, combining deductive categories derived from the literature with inductive insights emerging from the case data. A comparative analytical framework is applied to identify similarities and differences in how AI is operationalized across the selected companies.

The case study analysis encompasses three companies selected on the basis of the availability of publicly accessible data indicating the use of AI-driven sustainable marketing in their operations, as well as documented outcomes in terms of consumer engagement and environmental responsibility.

The thematic analysis is grounded in key categories identified in the literature: AI-driven personalization, sustainability, consumer engagement, and ethical and transparent practices.

This methodological design enables a systematic comparison of corporate practices and facilitates the integration of theoretical perspectives with empirical observations. However, the study is limited by its reliance on secondary data sources and the absence of direct access to proprietary corporate AI systems.

4 Results

Nike, Starbucks, and Nestlé operate in different business sectors and follow distinct business orientations (Nike is product-oriented with a focus on sports footwear and apparel; Starbucks is service-oriented; and Nestlé is product-oriented with a focus on food and beverages). The following section of the analysis presents the ways in which AI is utilized within the domain of digital marketing.

Nike implements sustainable practices across the entire value chain, starting from product design and manufacturing to product distribution, with the aim of reducing emissions and eliminating waste. The application of AI is reflected in the following segments:

Nike Fit: AI is used to determine the optimal shoe size based on individual foot measurements. The AI model calculates the most suitable size for each Nike shoe model using Nike Fit, a digital feature integrated into the Nike app that employs computer vision, machine learning, and AI to scan foot dimensions via a smartphone camera and accurately measure the shape, length, and width of both feet. Nike Fit is also used in retail stores to assist sales staff in recommending the most appropriate shoe size for each customer (Nike unveils Nike Fit, n.d.).

Move to Zero: A program aimed at achieving zero carbon emissions and zero waste, including the development of products made from recycled materials (Nike, n.d.). The company reported its contributions to sustainability in 2024 (Nike, n.d.), including the following achievements:

- A 69% reduction in absolute Scope 1 and Scope 2 greenhouse gas (GHG) emissions from Nike's own operations.
- A 36% reduction in absolute Scope 3 GHG emissions related to Nike's manufacturing and transportation activities.

- 96% of electricity consumption across Nike’s global operations sourced from renewable energy.
- 100% of operational waste generated by Nike’s strategic finished-goods suppliers diverted from landfills, with more than 60% reused or recycled.
- Less than 1% of inbound air freight used for transporting Nike products.
- A more than 40% reduction in freshwater (potable water) consumption among Nike’s material suppliers over the past decade.

Nestlé’s marketing campaigns emphasize environmentally responsible practices, including the use of packaging made from recycled or biodegradable materials, the promotion of products with a reduced environmental footprint, and transparent communication regarding sustainable suppliers and the ethical sourcing of raw materials. In addition, the company highlights initiatives aimed at food redistribution across the country, as well as the reduction of food waste, operational costs, and carbon emissions (Hall, 2025).

The key characteristics of the identified food waste include edibility, lack of economic viability for sale, and an excessively short shelf life. According to company estimates, approximately 700 tons of high-quality food—equivalent to 1.5 million meals—could be saved, thereby preventing up to 1,400 tons of CO₂ emissions and generating savings of up to £14 million in operational costs.

Nestlé employs the Zest software solution, which enables the redistribution of surplus food to more than 8,000 charitable organizations and local communities across the United Kingdom. The implementation of this system resulted in a reduction of edible food waste by more than 87% in one factory during the first two weeks of the pilot period (Hall, 2025).

The research identified key aspects of AI utilization at Nestlé, including:

- Creation of personalized content using digital twins for generating high-quality product visuals for e-commerce and digital media (Nestlé is creating AI-powered ‘digital twins’ for brands like Purina, Nescafé Dolce Gusto, and Nespresso, 2025). Digital twins, as 3D replicas of physical products, enable digital customization or localization of product packaging across different

environments. New creative content can be generated using AI without the need for reshooting.

- AI for revitalizing and adapting legacy advertisements for digital and social media platforms. Using Reelmind.ai, the company modernized classic ad campaigns such as Nescafé Gold Blend and KitKat Break (Nestlé’s marketing magic: AI recreation of classic ad campaigns with modern twists, 2025). Key aspects of campaign revitalization include enhancing the resolution of old ads, employing AI to generate additional scenes, and integrating content for social media and interactive formats.
- AI for consumer experience personalization (Nestlé, 2021)
- Nestlé employs AI chatbots, such as Cookie Coach, which respond to consumer questions regarding recipes and preferences. This represents a component of personalized digital marketing and user engagement.
- AI as a digital assistant and customer support tool (Hamstra, 2021)

The company also utilizes Toll House as a digital baking assistant that doubles as customer support. Toll House features a photorealistic video avatar, Ruth, who leverages AI to answer baking-related questions, resolve issues that arise during the baking process, and assist users in creating personalized cookie recipes.

Starbucks implements various digital campaigns that combine personalization of the customer experience with sustainable initiatives, including reducing plastic usage, promoting recycling, and supporting sustainable coffee suppliers (Starbucks Coffee Company, 2026). Starbucks leverages AI through the following tools:

- Green Dot Assist – An AI-powered tool that functions as a real-time companion for café partners, providing quick responses ranging from recipe guidance to service information (Phanse, 2026).
- Smart Queue – AI technology that optimizes order flow within the café, enabling faster and more efficient delivery of orders to customers while intelligently scheduling employee shifts (Phanse, 2026).
- Deep Brew – An internal AI system that employs machine learning to enhance business operations and customer experience. The system analyzes data from 17 million app users to personalize messaging, optimize staff schedules, and manage inventory. Implementation of Deep Brew has resulted in a 30% increase

in return on investment and a 15% growth in customer engagement (Chapman, 2026). Deep Brew analyzes data from the Starbucks Rewards app to personalize offers and improve the customer experience. In 2026, Starbucks redesigned its loyalty program to encourage upgrades to higher membership tiers, thereby strengthening engagement and increasing transaction volume (Starbucks Coffee Company, 2026). Different loyalty levels—Green, Gold, and Reserve—allow AI to accurately segment members and create personalized campaigns for each segment.

When using the mobile ordering app, AI systems can track customer choices, tailor future recommendations, and offer discounts for reusable cups based on consumer habits. These predictions also enable more accurate inventory planning and waste reduction in line with the Reusable Revolution program. Starbucks has developed several sustainability initiatives, including:

- Towards a Sustainable Cup – Cold beverage cups containing 10–20% less plastic, compostable or paper straws, and recyclable lid stickers replacing traditional plastic plugs; customers using their own reusable cup receive a \$0.10 discount on beverages (Starbucks Coffee Company, n.d.).
- C.A.F.E. Practices – An ethical coffee sourcing program that promotes sustainable cultivation practices based on over 200 indicators assessing farms according to economic, social, and environmental criteria. AI assists in monitoring supplier data, identifying areas requiring improvement or intervention, and highlighting the most effective coffee cultivation practices (Starbucks Coffee Company, n.d.; Starbucks Coffee Company, 2024).

Based on the analysis of the three companies, the following characteristics of AI usage can be identified: personalization, enhancing customer practices and ethics (Table 1):

Table 1: AI - context digital marketing

Contributions	Nike	Nestle	Starbucks
Personalization	Nike Fit	Digital twins	Deep Brew
Enhancing customer experience	Nike Fit - korisnička podrška	Chatbots	Loyalty program
Sustainable practices	Move to Zero	Zest software	Reusable cups, reduced plastic, sustainable coffee sourcing
Ethics	Ethical sourcing	Ethical sourcing, transparent reporting	Monitoring supplier practices, ethical coffee cultivation

Source: author, based on research

5 Analysis and discussion

The integration of technology and ecological initiatives contributes to stronger consumer engagement and a reduced environmental footprint, in line with theoretical and empirical findings on AI and sustainable marketing (Hollensen, Kotler & Opresnik, 2017; van Esch & Stewart Black, 2019; Puntoni et al., 2021).

Analyses indicate that personalized campaigns enhance customer loyalty and encourage positive behavior toward sustainable practices. Consumers who receive digital reminders about reusable cups or sustainable products are more likely to use them, reducing waste and increasing the social value of the campaigns.

AI-driven campaigns also boost consumer engagement and brand loyalty, particularly among customers who value sustainability. Precise targeting minimizes unnecessary promotional materials, further contributing to waste reduction. Beyond personalization, AI improves operational efficiency and customer convenience. Starbucks' Smart Queue optimizes order flow and staff scheduling, reducing wait times, while Nike Fit supports in-store sales personnel, and Nestlé's Toll House digital assistant guides users through personalized baking experiences. These tools demonstrate how AI enhances the holistic customer experience by combining digital and physical touchpoints, resulting in measurable improvements in satisfaction and engagement (Chapman, 2026; Hamstra, 2021).

Sustainable Practices Sustainability is a core component of AI integration for all three companies. Nike's Move to Zero program, supported by AI analytics, has led to significant reductions in greenhouse gas emissions, energy consumption, and operational waste. Nestlé leverages AI for food redistribution (via Zest software), eco-packaging, and responsible sourcing, while Starbucks uses AI predictions to support reusable cup programs and sustainable coffee sourcing through the C.A.F.E. Practices framework. These initiatives highlight how AI enables companies to optimize resource use, reduce environmental impact, and align business operations with sustainability goals (Nike, n.d.; Starbucks Coffee Company, n.d.; Hall, 2025).

Ethical Practices and Transparency AI, also, supports ethical decision-making and transparency. Nestlé and Starbucks use AI to monitor supply chains and identify areas requiring intervention, while Nike ensures ethical supplier practices and waste management. Transparent communication of sustainability metrics, combined with AI-driven monitoring, strengthens stakeholder trust and reinforces the companies' reputations as responsible corporate actors (Zeng et al., 2021; Puntoni et al., 2021).

6 Conclusion

Artificial intelligence in the context of sustainable digital marketing enables advanced personalization and data-driven customer analysis, resulting in more precise targeting and a reduction in unnecessary resource consumption. However, the effectiveness of AI implementation is not solely technical, but also depends on transparent data governance and ethical management practices, which play a critical role in building consumer trust and ensuring long-term brand credibility.

The case studies of Nike, Nestlé, and Starbucks illustrate that AI can function as an integrative mechanism linking operational efficiency, customer experience, and sustainability objectives. Across the analyzed cases, AI-driven systems contribute to the optimization of resource allocation and the reduction of environmental impact through improved targeting and predictive analytics. The analysis indicates that companies across different sectors (product- and service-oriented) integrate AI into digital marketing strategies in distinct ways aligned with their business models and sustainability objectives.

Nevertheless, differences in strategic emphasis are evident: Starbucks primarily focuses on supply chain optimization and waste reduction, Nestlé emphasizes personalization to minimize product and packaging waste, while Nike integrates AI with sustainability-oriented branding strategies, including recycling initiatives and digital customization.

Overall, the findings suggest that AI is not merely an operational tool, but a strategic enabler of sustainable marketing transformation, facilitating alignment between business performance, consumer engagement, and environmental responsibility. At the same time, the analysis highlights that the impact of AI is contingent upon ethical implementation, transparency, and the continuous adaptation of corporate strategies to evolving consumer and environmental expectations. In addition to the aforementioned contributions, the study also has certain limitations. The analysis is based on a limited number of companies, which affects the generalizability of the results across all industries or markets. Additionally, small and medium-sized enterprises and local initiatives were not included. The analysis of campaigns is primarily qualitative and descriptive rather than quantitative, which may limit the precise measurement of AI's effects on consumer behavior and sustainability.

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CONTEMPORARY CONCEPTS OF DIGITAL MARKETING CAMPAIGNS: ARTIFICIAL INTELLIGENCE AND ENVIRONMENTAL RESPONSIBILITY

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In the context of digital transformation, digital marketing campaigns are implemented as an integral part of digital business models. Within these models, companies adopt omnichannel management approaches that integrate digital and physical channels, providing customers with a seamless, consistent, and connected experience. This paper examines key performance indicators of digital marketing campaigns with diverse objectives, including environmental responsibility, the enhancement of environmental awareness, and other socially relevant issues, as well as the relationship between investment levels and target audiences. The analysis is conducted through a case study of campaigns implemented by Costa Coffee. In addition, the paper analyses key performance indicators and critical responses to a digital marketing campaign created with the support of artificial intelligence, using the example of Coca-Cola. The study applies a qualitative research methodology based on a descriptive-analytical approach and the analysis of secondary data sources. A case study method and comparative analysis are employed to examine the advantages, limitations, and potential risks associated with the use of artificial intelligence and environmentally oriented campaigns in comparison with other forms of digital marketing campaigns.

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1 Introduction

Digitalization has also led to significant changes in business models and the emergence of a new concept: the digital business model (Verhoef & Bijmolt, 2019). A digital business model represents the way in which an organization creates, delivers, and captures value through digital technology. This involves not only the use of the Internet and digital platforms in creating and delivering value but also the transformation of business operations, customer relationships, and revenue structures. Digital business models encompass four dimensions: digital channels, digital customers, digital infrastructure, and digital products and services (Verhoef et al., 2021).

In addition to digital business models, companies implement omnichannel management, a strategy for integrating and coordinating all channels through which a company communicates with consumers and sells products or services, ensuring that the customer experiences a seamless, unified, and connected journey regardless of the channel used. While multichannel management involves presence across multiple channels (physical stores, website, mobile application, social media), omnichannel implies that all these channels are interconnected, so the consumer experience is uninterrupted when switching from one channel to another. The omnichannel approach integrates digital and physical channels to provide customers with a unified brand interaction (Verhoef et al., 2015).

Omnichannel retailers use ICT to enable information continuity and personalized communication with consumers (Piotrowicz & Cuthbertson, 2014). Companies employing diverse social media strategies—i.e., presence across multiple platforms—achieve better outcomes than those focusing on fewer platforms, increasing overall online sales by 2% to 5% (Wand et al., 2025).

Companies should measure the performance outcomes of marketing campaigns (KPIs) using various indicators. KPI targets are set as SMART objectives (Macready, 2025).

The research objectives of this study focus on identifying KPI indicators for measuring the ecological impact of campaigns as an important component of contributing to sustainable development based on a case study: Costa Coffee's Campaign Effectiveness and Environmental Impact.

2 Metodology and literature review

A qualitative research methodology was applied in this study, based on a descriptive-analytical approach. The research relies on the analysis of secondary data sources, including relevant scientific and professional literature in the fields of digital marketing, digital business models, and omnichannel management.

In addition, the case study method was employed through an analysis of the digital marketing campaigns of Costa Coffee, with the aim of identifying key performance indicators of campaigns that integrate sustainability objectives, social responsibility, and environmental awareness.

The objectives of this study are:

- To analyze the role of digital marketing campaigns within contemporary digital business models and omnichannel management.
- To identify key performance indicators of digital marketing campaigns in the context of digital transformation.
- To examine the ways in which digital marketing campaigns integrate sustainability objectives, including a responsible approach to the environment and the strengthening of environmental awareness.

The literature review indicates that it examines digital tools in marketing strategies (Kotler & Keller, 2016; Chaffey & Ellis-Chadwick, 2019). Digital marketing strategies are essential for brand promotion and ensuring sustainability in the tourism and hospitality industry (Kamyabi et al., 2025).

In addition to the role of digital tools, studies also examine the role of AI as support for digital marketing strategies. The study by Acatrinei et al., (2026) explores how AI influences consumer behavior and sustainable digital strategies through mobile and

social media platforms, including empirical findings on trust, transparency, and the acceptance of AI tools in marketing. AI has a positive impact on consumer experience and consumer engagement on social media (Bilal et al., 2024).

The contribution of AI to digital marketing is reflected in the personalization of customer experience, the optimization of strategies, and its contribution to sustainable business practices (Gündüzyeli, 2024; Jarek & Mazurek, 2019). In addition, studies address the issue of green marketing in the context of business digitalization, emphasizing (Alkhatib et al., 2023) that marketing campaigns created using AI contribute to higher KPIs (Klein & Kutlar, 2024). Schultz et al., (2011) highlight the role of integrated marketing communications in social responsibility and brand sustainability through digital platforms. Sustainable marketing initiatives contribute to the achievement of the SDGs (Anuradha et al., 2023), as does green marketing (Peattie & Crane, 2005).

The aforementioned studies indicate a segmented approach to the role of digital campaigns, AI as support for digital tools, KPIs, and integrated marketing communications, whereas the study in this paper focuses on synthesizing all these aspects within the framework of the analyzed case study.

3 A case study: Costa Coffee's Campaign Effectiveness and Environmental Impact

This paper analyzes three digital marketing campaigns implemented by Costa Coffee from the perspective of their objectives, applied digital tools, and key performance indicators: Behind Every Cup, Costa Express, and Sustainability First Campaign. The campaigns were selected based on data availability and comparability, as well as the diversity of objectives and performance indicators (Marketing Maverick, 2025).

Behind Every Cup was implemented with the objective of demonstrating to customers the coffee preparation process in Costa Coffee outlets. The campaign was carried out through video content featuring baristas preparing beverages, from tamping the coffee to carefully steaming the milk. The company aimed to highlight its commitment to quality and employee expertise, thereby fostering customer trust and respect.

Costa Express is a campaign based on a product quality guarantee, acknowledging potential customer dissatisfaction with beverages purchased from Costa Express machines. The company announced that customers who were not satisfied with a drink purchased from a Costa Express machine would receive a complimentary handcrafted beverage in a Costa outlet. Clear signage was placed on Costa Express machines explaining how customers could redeem this guarantee.

Costa For Everyone is a campaign designed to demonstrate that the company offers products tailored to different customer segments. The company restructured its menu to emphasize various options available at different times of the day and for different consumer profiles. Special offers for students were also introduced and promoted in proximity to universities.

The Sustainability First Campaign was implemented with the objective of demonstrating the company's commitment to environmental sustainability through the following activities:

- Designing new cups that are fully recyclable;
- Installing recycling points in every store;
- Rewarding customers who brought their own reusable cups with additional loyalty points as an incentive.

The campaign encouraged activities aimed at waste reduction, education, and motivating customers toward more environmentally responsible behavior. The company created a panel in each store displaying the number of cups recycled and the amount of plastic saved. Store staff underwent training in order to explain this environmental initiative to customers.

The analysis and discussion of the results are conducted from the perspective of the key characteristics of omnichannel management in marketing campaigns, as well as the fundamental elements of digital marketing strategy and the marketing plan. The key characteristics of the omnichannel approach analyzed in the campaigns include:

Unified customer experience: Customers can initiate a purchase on one channel, continue it on another, and complete it on a third—without losing data or context. Customers no longer differentiate between physical and digital channels; they expect an integrated experience, which requires a high level of internal resource coordination (Brynjolfsson & Hu, 2013).

Integrated customer data: All customer data are collected within a unified system, enabling personalization and real-time tracking of customer behavior.

Coordination of marketing, sales, and logistics: All company functions operate in synchronization—social media activities are aligned with in-store inventory. Consumers expect consistency in communication, pricing, and services regardless of the channel (Rigby, 2011).

Consumers who purchase beverages from Costa Express machines are able to redeem a handcrafted beverage in a Costa Coffee store, ensuring integration between automated and physical retail channels.

Behind Every Cup: A dedicated website was developed where customers could “meet” their local baristas and learn coffee preparation tips, thereby extending the in-store experience into the digital environment.

Costa Express: The campaign involved well-known social media influencers who recorded themselves trying Costa Express machines at various locations—such as petrol stations, supermarkets, and railway stations. In addition, radio advertisements were broadcast during morning time slots, when consumers are most likely to consider purchasing coffee. The campaign, also, included staff training at locations where Express machines were installed, enabling employees to assist customers in using the machines and to explain the quality guarantee.

Within the analyzed campaigns, the element of integrated customer data was not identified, as no publicly available data related to this aspect were provided.

Furthermore, in 2021, Costa Coffee launched its first TikTok campaign, The Costa For You. The campaign consisted of 14 video advertisements that were personalized and displayed to users based on TikTok’s search algorithm (Marketing

Communication News, 2021). Entertaining characters created באמצעות eye and mouth filters explained different ways to enjoy Costa Coffee products.

The presented results indicate that Costa Coffee selects social media platforms that influence consumer behavior and marketing outcomes, while aligning them with the objectives of the specific campaign (Wirtz et al., 2013).

The analysis of the implemented campaigns demonstrates that the fundamental elements of the digital marketing strategy and marketing plan of Costa Coffee include:

- Use of digital tools: Within the Sustainability First Campaign, the company began cooperating with local authorities to ensure the proper recycling of its cups. Digital screens were installed in stores to display real-time data on environmental impact—for example, the number of trees saved due to the use of reusable cups on a given day.
- The Costa Coffee Club loyalty program was designed to reward regular customers (Berohn, 2024). For every penny spent, customers accumulate points that can later be redeemed. The introduction of this program encourages repeat visits and fosters long-term loyalty. Integration with the mobile application enhances convenience, allowing customers to order in advance, pay digitally, and skip queues, which represents a significant advantage for busy professionals.
- Personalized offers based on previous purchases contribute to a tailored and carefully designed customer experience.
- Presence on social media: active communication with consumers.
- Measurement of digital marketing campaign effectiveness and return on investment.
- Promotion of environmentally responsible business practices through the company's website and social media channels.

On the company's website, two articles—Recycling Paper Cups and Partnership for Collection and Recycling—clearly highlight Costa Coffee's environmental initiatives (Costa Coffee, n.d.).

Recycling Paper Cups – The company emphasizes its commitment to improving recycling infrastructure, supporting collaborative recycling initiatives, and exploring new cup design technologies to make recycling easier.

Partnership for Collection and Recycling – In 2018, the company participated in establishing the National Cup Recycling System in the United Kingdom. Within this system, Costa Coffee financially supports cup recycling by providing incentives to waste collectors for each ton of cups collected for recycling. Customers are encouraged to recycle takeaway paper cups at participating stores. Thanks to this program, more than 200 million cups have been recycled to date.

4 Key Performance Indicators of Marketing Campaigns

Key performance indicators (KPIs) of marketing campaigns can be classified into five categories (Macready, 2025):

1. Engagement KPIs
2. Awareness KPIs
3. Conversion KPIs
4. Customer Care KPIs
5. Content Performance KPIs

The indicators marketing campaigns are grouped into five categories of KPIs (Table 1).

The analysis indicates that all campaigns achieved Customer Care KPIs, which, in the case of the Sustainability First Campaign, reflect corporate social responsibility and environmental stewardship. These indicators accounted for 23.3% of the total KPIs reported across the campaigns, while Conversion KPIs represented 33.3%. The Conversion KPIs demonstrate that campaign success rates increased across various omnichannel management sources. No campaign achieved success indicators within to the Content Performance KPIs category.

Table 1: KPIs

Indicators	Behind Every Cup	Costa Express	Sustainability First Campaign
Engagement KPIs	Instagram engagement increased by 218%	-	Use of reusable cups increased by 78%. 2.8 million customers joined the recycling program.
Awareness KPIs	TV advertisements reached 40 million viewers in the United Kingdom	-	Customer environmental awareness scores increased by 34%.
Conversion KPIs	Store visits rose by 8% during the campaign period.	Sales through Express machines increased by 32%. Machine usage rose from 52% to 67%. 1,000 new Express locations were added. Customer satisfaction with the machines increased from 71% to 89%.	-
Customer care KPIs	Brand trust index increased from 72% to 84%.	Only 0.5% of beverages were returned (using the quality guarantee).	Saved 12.6 million single-use cups. Reduced plastic usage by 45 tons.
Content performance KPIs	-	-	-

Source: author, based on Marketing Maverick, 2025.

Measuring ROI helps assess the success of marketing campaigns through the use of relevant metrics and KPIs (Lenskold, 2003). However, despite the positive impact of the Sustainability First Campaign on sustainable development and the circular economy, this campaign yielded the lowest return on investment for the company - \$2.10 per \$1 invested (Table 2).

Table 2: Return ROI

Return	Return on investment (\$)	Financial gap
Lowest	2.1	-1,1
Average	3.2	-

Source: Marketing Maverick, 2025.

Coca-Cola utilized advanced AI and predictive analytics to identify demand for low-calorie products six months before corresponding sales data became available (Zahara, 2025). The implementation of this strategy resulted in an 18% increase in ROI (Cherian et al., 2025).

By applying AI-driven analytics for real-time consumer data analysis, optimization of advertising expenditure, and campaign performance evaluation, the company improved ROI by 22%, as budgets were reallocated toward campaigns with higher engagement levels (Zahara, 2025).

Click-through rates increased by 18–22% when the AI system generated and evaluated creative advertisements in real time, thereby enhancing digital advertising performance during the 2023 FIFA World Cup campaign (Ramnani, 2024).

5 Conclusions

The study's findings confirm that the success of digital marketing campaigns depends on a combination of an omnichannel approach, the integration of digital tools and AI, and the establishment of relevant KPIs. The analyzed campaigns were not created using AI; however, AI was indirectly present in identifying key consumer preferences, algorithms for personalized offers, and other functions. The combination of digital tools and AI contributed to high KPI values and ROI. Nevertheless, the study highlights differences in returns across campaigns, with the largest monetary gap observed in the campaign that most significantly contributed to environmental protection and the enhancement of ecological awareness.

The limitations of this study lie in the absence of data for campaigns generated by AI; consequently, there are no available KPI or ROI metrics, which prevented a comprehensive comparative analysis of the advantages of digital tools versus AI. This, however, does not diminish the value of the study, which can serve as a foundation for further research, particularly regarding the relationship between campaigns focused on sustainability and those not primarily oriented toward it.

The effectiveness of digital marketing campaigns was achieved through an omnichannel approach, demonstrating the use of various social media channels to strengthen the customer experience. Additionally, one campaign combined

traditional and digital marketing, which contributed to increased foot traffic in stores.

The campaigns aimed to enhance customer experience and brand satisfaction, as evidenced by KPI indicators. The conclusions of the study emphasize the need to measure the results of each campaign to better understand its effects and to improve future activities. Loyalty programs contribute to customer experience and conversion rates and serve as an element for planning future campaigns.

Moreover, the ecological impact of the campaigns represents an important indicator of sustainability and corporate social responsibility. Costa Coffee largely leverages digital transformation for digital marketing campaigns, but greater integration with AI could open new opportunities for enhancing marketing activities and customer engagement.

The use of digital technology and AI in sustainable marketing initiatives contributes to reduced resource consumption, decreased plastic usage, and increased recycling awareness. Such practices should be incorporated into digital campaigns by other companies as well, prioritizing environmental benefits over purely financial gains.

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ELECTRIC MOBILITY AND TOURISM – DESIGNING A MODEL FOR CHARGING INFRASTRUCTURE IN SEASONAL TOURISM REGIONS

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The growing share of battery electric vehicles (BEVs) poses new challenges for tourism regions, which are typically characterized by strong seasonality. Charging infrastructure must be sufficiently dimensioned to meet peak demand during the high season, while utilization drops sharply in the low and off-season, raising concerns about economic viability. This paper develops a modeling framework that calculates a seasonal charging coverage ratio and integrates an economic efficiency analysis. Using a case study of a summer destination on the southern European coast, the model quantifies seasonal charging demand, infrastructure capacity, and key economic parameters. The results reveal a structural imbalance: demand during the high season approaches infrastructure capacity, while extended periods of low demand create significant overcapacity and insufficient utilization. Consequently, the charging infrastructure generates an overall annual loss. The proposed modeling framework provides a transferable analytical framework that supports evidence-based charging infrastructure planning in highly seasonal tourism destinations.

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1 Introduction

The transition to electric mobility is accelerating. In September 2025 alone, global sales of electric cars and plug-in hybrids rose by 26 percent to a record 2.1 million vehicles. In Germany, sales of purely electric cars rose by 45 percent in the third quarter, and in Spain by as much as 100 percent (Schmidt, 2025). It is therefore foreseeable that this will have consequences for tourist destinations that are usually reached by car, such as the coastal regions of southern Europe or ski resorts in the Alps. These developments require the expansion of charging infrastructure needed to supply electric vehicles. According to recent studies, this charging infrastructure is of great importance, as awareness of sustainable travel is growing steadily and a well-developed charging infrastructure is becoming increasingly important as a competitive factor for holiday destinations (Bornefeld, 2023). For tourist destinations, the question now arises as to the extent to which such a charging infrastructure should be expanded in terms of the number of charging options and the respective power output of the charging facilities against the backdrop of the typical annual seasonal cycle (high season, low season, off-season).

The aim is to address this problem by developing a model that uses specific parameters to calculate a “charging coverage ratio” that indicates the utilization of the charging infrastructure per season. In a further step, the economic efficiency of the charging infrastructure is also calculated. For this purpose, an Excel-based data collection and analysis tool (Charging Station Calculator Tool, abbreviated: CSC tool) is used. The contribution lies in linking seasonal demand modeling with economic viability assessment in a single framework.

2 Theoretical background/Literature review

Tourism is an important economic and employment sector both in Europe and worldwide. In 2025, the travel and tourism sector is expected to contribute nearly €1.9 trillion to the EU's GDP, accounting for 10.5% of the EU economy. The number of people employed is expected to reach almost 26 million, accounting for 12% of all jobs in the EU – a clear sign of the growing importance of the sector (WTTC, 2025). For many European countries, tourism is one of the most important economic factors.

According to Eurostat, the share of GDP generated by international tourism in selected EU countries in 2023 was around 18.7% in Croatia, around 10.6% in Cyprus, around 9.6% in Malta, and around 9.5% in Portugal (Eurostat, 2025a). Looking at individual holiday regions, a strong seasonal pattern emerges. In one in six EU regions, more than 40% of annual overnight stays occur in just two months of the high season, with this seasonal effect being particularly pronounced in coastal regions (Eurostat, 2025b). When looking at the modal split, i.e., the choice of transport mode, an average view is not very meaningful, as some destinations (e.g., islands) are usually reached by plane or ship rather than by car. However, it is striking that some holiday destinations are characterized by above-average car travel, including Croatia with 70% and Slovenia with 69% (Eurostat, 2025c).

Based on a study by the European Automobile Manufacturers' Association (ACEA), a distinction should be made between private and public charging (ACEA, 2022). Private charging is restricted in terms of access, either by private ownership or a hotel. Public charging stations are freely accessible, except for semi-public charging stations (e.g., in parking garages). Depending on the power output of public charging stations, a distinction can be made between slow or normal charging (alternating current charging, charging power approx. 4–22 kW, hereinafter referred to as normal (AC) charging), fast charging (direct current charging, charging power approx. 150 kW, hereinafter referred to as fast (DC) charging) and ultra-fast charging (high-power charging (HPC), charging power approx. 400 kW). A recent study by the International Energy Agency (IEA, 2025) provides an overview of the current situation and an outlook for the near future of charging infrastructure expansion.

3 Methodology

The steps for performing calculations with the CSC tool are explained below. Two Excel worksheets are used for each of the two calculation areas, “Charging coverage ratio” and “Economic efficiency”, which are supplemented by additional worksheets with supplementary parameters. For the sake of simplicity, the specific assignment to the individual Excel areas is not discussed below. To increase the informational value of the explanations, sample data from a modeled case study is used below. The case study is based on the assumption of a summer destination on the coast of Southern Europe. The case study serves as an exemplary scenario and does not claim to be statistically representative. Instead, the model aims to demonstrate a

transparent analytical structure that can be adapted to different tourism destinations by adjusting a limited set of input parameters. The model is based on a set of simplifying assumptions that aim to ensure transparency and reproducibility rather than exact prediction accuracy. Key assumptions include constant average charging volumes, simplified seasonal utilization rates, and a stylized representation of tourist behavior. These assumptions are intentionally chosen to highlight structural relationships between demand, capacity, and economic performance. The model does not aim to predict exact real-world outcomes but rather to illustrate structural relationships. Therefore, results should be interpreted as scenario-based insights rather than precise forecasts.

3.1 Guest Calculation

The case study does not represent a specific destination but reflects a stylized Mediterranean summer tourism region based on typical accommodation capacities and seasonal occupancy patterns reported in European tourism statistics. The objective is not statistical representation but the illustration of structural relationships between seasonal demand and infrastructure capacity.

The starting point for this is the calculation of bed capacity, which is determined using the parameters “number of accommodation establishments” ($n=726$) and “average capacity of accommodation establishments (in beds, $n=30$)”. For this case study, a bed capacity of 21,780 beds is therefore assumed. This bed capacity is utilized differently in the defined vacation periods (high season, low season, and off-season). The average length of stay for EU citizens in other EU countries is approximately seven days (Eurostat, 2025c). For reasons of model simplification, all visitors are assumed to have an average length of stay of seven days. This assumption allows for a consistent derivation of weekly arrival and loading requirements. By assuming an average bed occupancy rate per season, it is possible to determine the number of guests arriving in the destination region per week.

Table 1: Guest calculation

Season type	High season	Low season	off-season	Total
Season weeks	16	22	14	52
Length of week in days	7	7	7	
Average holiday stay period (in days)	7	7	7	
Maximum tourist bed capacity	21,780	21,780	21,780	
Bed capacity utilization rate	70%	30%	1%	
Arriving guests per week	15,246	6,534	218	

Source: author's compilation

The very low bed occupancy rate in the off-season deliberately reflects a scenario in which only a few businesses are open all year round.

3.2 BEV calculation

In this section, the calculated number of visitors is used to estimate the number of battery electric vehicles (BEVs) that will require charging infrastructure during a season. The calculation of the number of visitors arriving by car is based on the modal split parameter for passenger cars in Germany (Statista, 2025a). For the different seasons, an assumption is made about the number of people in the vehicle. The average number of people per vehicle is statistically 1.46 (Bundestag, 2018). For the case study, different assumptions are made. The values used are significantly higher than the statistical average, as tourist trips are usually made with several people per vehicle, e.g., families with children. These parameters are used to determine the number of vehicles arriving in the destination each week. The 20% share of battery electric vehicles (BEVs) is based on current European market trends and is used as a scenario parameter rather than a forecast value (Statista, 2025b). This now allows the number of BEVs arriving each week to be calculated. Considering private charging processes, the share of BEVs that require public charging infrastructure is determined.

The proportion of private charging is estimated and mainly relates to charging stations at accommodation providers (e.g., hotels). Due to the closure of hotels outside the high season, this value varies depending on the season. This results in a value that describes the average number of BEVs present at the same time that require public charging network during a typical stay.

Table 2: BEV calculation

Season type	High season	Low season	off-season
Arriving guests per week	15,246	6,534	218
Modal split (private car)	80%	80%	80%
Guests arriving with vehicles	12,197	5,227	174
Persons per vehicle	4	3	2
Arriving vehicles per week	3,049	1,742	87
Share of BEV	20%	20%	20%
Arriving BEVs per week	610	348	17
Share of private charging	20%	10%	5%
Share of public charging	80%	90%	95%
Average number of BEVs simultaneously present and requiring public charging infrastructure per week	488	314	17

Source: author's compilation

3.3 Charging calculation

This section calculates how many charging processes are required per season. To do this, a value is first assigned that represents charging processes for vacation trips per visit. The values assumed for this study refer to a summer destination. For a typical winter destination, such as a week's skiing holiday, it would be appropriate to reduce these assumptions accordingly, as ski buses etc. are used. An additional charging process is assumed for the return journey. Charging demand is primarily determined by the full charge required for the return journey and less by the activities during the stay. The sum of both values is then multiplied by the number of BEVs to obtain the total number of average charging processes for all BEVs (per week/per season). Even in the off-season, there is still a minimum charging requirement, as a full charge is necessary for the return journey regardless of the intensity of the stay.

Based on an assumed average charging volume per charging process, the total seasonal energy requirement can be derived by multiplying the number of charging processes by the average energy transferred per process.

Table 3: Charging calculation

Season type	High season	Low season	off-season
Average number of BEVs simultaneously present and requiring public charging infrastructure per week	488	314	17
Charging processes for holiday trips	1.0	0.7	0.3
Full charge for return trip	1.0	1.0	1.0
Calculated average charging processes per BEV	2.0	1.7	1.3
Total number of required charging processes per week	976	533	22
Total number of required charging processes per season	15,612	11,730	301
Average charging capacity (amount of electricity transferred) (in kWh)	62.5	62.5	62.5
Energy requirement per week in kWh	60,984	33,323	1,345
Energy requirement per season in kWh	975,744	733,115	18,829

Source: author's compilation

The assumptions regarding charging frequency and energy demand per charging process are intentionally simplified in order to create a transparent and reproducible modeling structure. They represent plausible average values derived from current EV battery capacities and typical driving ranges rather than precise behavioural forecasts.

3.4 Public charging infrastructure and capacity calculation

To determine the charging coverage ratio, the capacity of the public charging infrastructure must be calculated on the supply side. To do this, both the theoretical and the realistically achievable charging capacity per season must be modeled.

The calculation is performed separately for normal (AC) charging and fast (DC) charging. High-power charging (HPC) is not considered for reasons of simplification. Seasonal assumptions regarding daily operating hours are made for charging. Although a day consists of 24 hours, it is unrealistic to assume continuous use of the public charging infrastructure. Therefore, a reduced number of effective hours of use per day is defined for each season, reflecting typical charging behavior during the day and lower demand at night.

Table 4: Public charging general parameters

Season type	High season	Low season	off-season
Hours per day	24	24	24
Usage hours of a public charging station	12	10	8
Usage hours rate in %	50%	42%	33%

Source: author's compilation

For the case study, the infrastructure was dimensioned so that the demands of the high season could be covered with a moderate safety margin.

An average charging capacity was assumed for each charging point, resulting in a theoretical charging capacity or charging potential per day. However, this theoretical capacity does not reflect actual operating conditions. Therefore, an average utilization factor is introduced to account for fluctuations in demand, idle times, and operational inefficiencies. Multiplying the theoretical capacity by this utilization factor gives the realistic daily charging potential per charging point.

The realistic total energy supply per season is then determined by multiplying the realistic daily capacity of a charging station by the number of installed charging stations and the number of weeks in the season.

In addition to the energy-based capacity calculation (kWh per season), the number of possible charging processes is determined. This is calculated by dividing the effective daily hours of use by the average charging time per vehicle. The resulting theoretical number of charging processes per charging point is then adjusted by a seasonal utilization factor to obtain a realistic estimate of daily charging processes. This value can then be extrapolated to weekly and seasonal values.

The model therefore evaluates public charging capacity based on two dimensions:

1. Energy potential (in kWh)
2. Operational capacity (number of charging processes)

This dual perspective ensures consistency with the previously calculated demand indicators (energy demand and charging processes) and enables the derivation of the charging coverage ratio as the ratio between seasonal demand and seasonal supply.

For normal (AC) charging, 100 installed charging points are assumed, each with a charging capacity of 11 kWh.

Table 5: Normal (AC) charging parameters

Season type	High season	Low season	off-season
Ad 1) Calculating Energy potential			
Number of public charging points: Normal (AC) charging	100	100	100
Average charging capacity (amount of electricity transferred) (in kWh) for one charging station	11	11	11
Theoretical charging potential (kWh/day)	132	110	88
Average utilization factor in %	30%	20%	10%
Realistic charging potential (kWh/day)	39.6	22.0	8.8
Realistic charging potential (kWh/day) for all charging points	3,960	2,200	880
Realistic charging potential (kWh/day) for all charging points per week	27,720	15,400	6,160
Realistic charging potential in kWh for all charging points per season	443,520	338,800	86,240
Ad 2) Calculating Operational capacity			
Average charging time (in hours)	4.0	4.0	4.0
Theoretical charging operations per day per charging point	3.0	2.5	2.0
Average utilization factor in %	30%	30%	30%
Operational capacity for one charging point	0.9	0.8	0.6
Operational capacity for all charging points	90.0	75.0	60.0
Operational capacity for all charging points per week	630.0	525.0	420.0
Operational capacity (for all charging points per season)	10,080.0	11,550.0	5,880.0

Source: author's compilation

For fast (DC) charging, a value of 10 charging stations is assumed, each with a charging capacity of 150 kWh.

Energy-based and operation-based capacities may deviate slightly because average charging volumes and charging times vary between vehicles.

Table 6: Fast (DC) charging parameters

Season type	High season	Low season	off-season
Ad 1) Calculating Energy potential			
Number of public charging points: Fast (DC) charging	10	10	10
Average charging capacity (amount of electricity transferred) (in kWh) for one charging station	150	150	150
Theoretical charging potential (kWh/day)	1,800	1,500	1,200
Average utilization factor in %	30%	30%	30%
Realistic charging potential (kWh/day)	540	450	360
Realistic charging potential (kWh/day) for all charging points	5,400	4,500	3,600
Realistic charging potential (kWh/day) for all charging points per week	37,800	31,500	25,200
Realistic charging potential in kWh for all charging points per season	604,800	693,000	352,800
Ad 2) Calculating Operational capacity			
Average charging time (in hours)	0.5	0.5	0.5
Theoretical charging operations per day per charging point	24.0	20.0	16.0
Average utilization factor in %	30%	20%	10%
Operational capacity for one charging point	7.2	4.0	1.6
Operational capacity for all charging points	72.0	40.0	16.0
Operational capacity for all charging points per week	504.0	280.0	112.0
Operational capacity (for all charging points per season	8,0640	6,160.0	1,568.0

Source: author's compilation

3.5 Charging coverage ratio

The charging coverage ratio indicates the relationship between charging demand and available public charging capacity. It is calculated by comparing the previously determined seasonal charging demand (in terms of energy requirements and number of charging processes) with the realistically achievable charging supply of the installed infrastructure. The charging coverage ratio is a new parameter that has been developed specifically for seasonal destinations.

Two dimensions are considered:

1. Energy-based Charging coverage ratio

$$\text{Coverage ratio}_{\text{energy}} = \frac{\text{Realistic charging potential (kWh/per season)}}{\text{Energy requirement (kWh/season)}}$$

2. Operation-based Charging coverage ratio

$$\text{Coverage ratio}_{\text{operations}} = \frac{\text{Realistic charging operations per season}}{\text{Required charging processes per season}}$$

Unlike conventional infrastructure planning metrics that focus solely on installed capacity or peak load estimations, the charging coverage ratio integrates seasonal demand fluctuations with realistically achievable operational capacity. This allows infrastructure adequacy to be evaluated under strongly varying seasonal demand conditions, which are typical for tourism destinations.

A ratio below 100% indicates insufficient charging capacity in the respective season, while a ratio above 100% indicates excess infrastructure capacity.

This dual perspective allows a differentiated assessment of the adequacy of the infrastructure. While the energy-based ratio reflects the ability to meet total electricity demand, the operation-based ratio captures potential bottlenecks caused by limited charging points or insufficient handling capacities. Both indicators are therefore necessary to assess seasonal bottlenecks and overcapacity effects.

Table 7: Charging coverage ratio

Season type	High season	Low season	off-season
Realistic charging potential in kWh for all Charging points per season	1,048,320	1,031,800	439,040
Energy requirement per season in kWh	975,744	733,115	18,829
absolute deviation	72,576	298,685	420,211
Energy-based Charging coverage ratio	107%	141%	2,332%
Operational capacity for all charging points per season	18,144	17,710	7,448
Total number of required charging processes per season	15,612	11,730	301
absolute deviation	2,532	5,980	7,147
Operation-based Charging coverage ratio	116%	151%	2,472%

Source: author's compilation

During peak season, the coverage ratio for electricity capacity is slightly above 100%. This means that, mathematically speaking, all demand can be met during the main season. The same applies to the low season, although the coverage ratio significantly

exceeds 100%. However, there is a dramatic overcapacity in the off-season, which is more than twenty times higher than in the peak season. The process-oriented calculation yields roughly the same picture. Good coverage in the peak and off-season is offset by very high overcapacity in the off-season.

4 Efficiency

In addition to the capacity analysis, an economic efficiency assessment of the charging infrastructure is carried out. The profitability calculation is based on a partial cost approach, distinguishing between variable electricity procurement costs and fixed infrastructure-related costs. This structure enables a transparent assessment of seasonal profitability while maintaining consistency with the previously derived demand data. Other cost components such as grid fees or land costs were deliberately not considered, as the focus is on structural economic efficiency.

Two important parameters determine the economic outcome. First, the electricity purchase price is assumed to be €0.38 per kWh. This value reflects a realistic procurement price under current European market conditions and considers the volatility of wholesale electricity markets. Second, seasonal electricity demand is derived directly from the charging demand model presented in Section 3, ensuring methodological consistency between the technical capacity analysis and the financial assessment.

Table 8 summarizes the basic economic parameters. The seasonal electricity demand corresponds to the calculated charging energy demand per season, which forms the basis for the subsequent yield and cost calculations. By combining energy demand volumes with procurement prices and assumptions about infrastructure costs, the model enables a seasonally differentiated profitability analysis. It is assumed that the majority of charging (85%) will be normal (AC) charging, with the remaining 15% being fast (DC) charging. It is also assumed that sales prices will fluctuate seasonally and that there will be a price difference between AC and DC charging.

Table 8: Basic parameters for efficiency

Season type	High season	Low season	off-season
Purchase price of electricity in Euro/kWh	0.38	0.38	0.38
Electricity demand in kWh	975,744	733,115	18,829
Normal (AC) charging			
Charging share in % Normal (AC) charging	85%	85%	85%
Charging volume Normal (AC) charging per period	829,382	623,148	16,004
Sales price of electricity	0.62	0.55	0.49
Fast (DC) charging			
Charging share in % Fast (DC) charging	15%	15%	15%
Charging volume Fast (DC) charging per period	146,362	109,967	2,824
Sales price of electricity	0.82	0.72	0.62

Source: author's compilation

The electricity procurement price should be interpreted as a scenario parameter rather than a fixed market value. The sensitivity examples presented in the discussion illustrate how changes in electricity prices or infrastructure size influence the economic results.

4.1 Efficiency of Normal (AC) charging

The first step is to determine the fixed cost structure of the normal (AC) charging infrastructure. The calculation includes investment costs (hardware and installation), economic life, annual maintenance costs, backend and payment system costs, and capital costs that reflect the opportunity costs of the invested capital. These components are aggregated to determine the annual fixed costs per charging point.

To ensure seasonal comparability, annual fixed costs are distributed proportionally to the duration of each season. This proportional distribution reflects the fact that infrastructure capacity must be maintained throughout the year regardless of the actual degree of utilization. Consequently, fixed costs remain structurally binding even in periods of low demand.

As Table 9 shows, the dominant cost driver for normal (AC) charging infrastructures is the large number of installed charging points ($n = 100$). Although the fixed costs per charging point appear moderate on an annual basis, the total seasonal fixed cost burden becomes significant when multiplied by the installed capacity. This structural characteristic plays a decisive role in the profitability assessment of off-peak seasons.

Table 9: Normal (AC) charging fixed costs

Season type	High season	Low season	off-season	Total
Sum of fixed costs per charging point p.a.	4,050	4,050	4,050	
Proportionate sum of fixed costs per charging point per period	1,246	1,713	1,090	4,050
Number of charging points	100	100	100	
Total of actual fixed costs all charging points per period in Euro	124,615	171,346	109,038	405,000

Source: author's compilation

Based on the fixed cost distribution shown above, the seasonal profitability of normal (AC) charging can now be assessed. Revenue per season is calculated by multiplying the AC charging volume by the respective seasonal sales price. Variable costs consist exclusively of electricity procurement costs and are therefore directly proportional to the charging volume.

The contribution margin corresponds to the difference between seasonal revenues and electricity procurement costs. It reflects the operating profitability of AC charging before taking infrastructure-related fixed costs into account. As shown in Table 10, the high season generates the largest positive contribution margin due to higher utilization and higher charging volumes.

Table 10: Normal (AC) charging profit calculation

Season type	High season	Low season	off-season	Total
Turnover p.a.	514,217	342,731	7,842	864,790
./. Variable costs p.a.	315,165	236,796	6,082	558,043
Contribution margin	199,052	105,935	1,760	306,747
./. Proportionate sum of fixed costs per charging point per period	124,615	171,346	109,038	405,000
Profit/Loss	74,436	-65,411	-107,278	-98,253

Source: author's compilation

However, after deducting the proportionately allocated fixed costs, the seasonal imbalance becomes clear. While the high season remains clearly profitable, the low season already leads to a deficit and the off-season to an even more significant loss. This result underscores the structural challenge of infrastructures with high fixed costs in a highly seasonal demand environment. Even though charging electric cars

generates positive contribution margins in all seasons, insufficient utilization outside peak times prevents full cost recovery on an annual basis.

4.2 Efficiency of fast (DC) charging

The proportion of fast (DC) charging is derived as a supplement to normal (AC) charging, based on the assumed charging behavior of visitors. In this case study, DC charging accounts for 15% of the total seasonal charging volume. Although DC charging accounts for a smaller share of the total energy demand, it plays a strategically important role due to higher charging speeds and time-critical demand patterns, especially during arrival and departure times.

The fixed cost structure of fast (DC) charging infrastructure differs significantly from that of normal (AC) charging infrastructure. Due to higher charging capacities and more complex technical requirements, the investment costs per charging point are significantly higher. In addition to the costs for hardware and installation, annual depreciation, maintenance costs, backend and payment system costs, and capital costs are also taken into account here.

As Table 11 shows, the annual fixed costs per DC charging station are significantly higher than for AC charging stations. However, since the number of DC charging stations installed is comparatively low ($n = 10$), the total seasonal fixed cost burden remains below that of a normal (AC) charging infrastructure. Nevertheless, the higher capital intensity of DC charging stations increases the financial risk in times of low utilization.

Table 11: Fast (DC) charging fixed costs

Season type	High season	Low season	off-season	Total
Sum of fixed costs per charging point p.a.	12,825	12,825	12,825	
Proportionate sum of fixed costs per charging point per period	3,946	5,426	3,453	12,825
Number of charging points	10	10	10	
Total of actual fixed costs all charging points per period in Euro	39,462	54,260	34,529	128,250

Source: author's compilation

Based on the fixed cost allocation, the seasonal profitability of fast (DC) charging can now be assessed. The calculation is performed in the same way as for normal (AC) charging profitability.

Due to the higher sales prices per kWh, DC charging achieves comparatively high contribution margins per unit of energy supplied. As shown in Table 12, the high season achieves a solid positive contribution margin that significantly exceeds the allocated fixed costs. However, the low season already shows a deficit, which widens further in the off-season.

Table 12: Fast (DC) charging profit calculation

Season type	High season	Low season	off-season	Total
Turnover p.a.	120,017	79,176	1,751	200,944
./. Variable costs p.a.	55,617	41,788	1,073	98,478
Contribution margin	64,399	37,389	678	102,466
./. Proportionate sum of fixed costs per charging point per period	39,462	54,260	34,529	128,250
Profit/Loss	24,938	-16,871	-33,851	-25,784

Source: author's compilation

Although DC infrastructure requires significantly higher investment per charging station, these high capital costs are partially offset by higher margins during periods of high demand. Similar to AC charging, however, underutilization during off-season months reduces overall profitability and increases financial risk.

4.3 Total Efficiency

The summary of seasonal results for AC and DC charging clearly shows the overall economic performance of the charging infrastructure. Table 13 summarizes the combined contribution margins and fixed costs for all seasons.

Table 13: Total efficiency

Season type	High season	Low season	off-season	Total
Sum of contribution margins	263,451	143,324	2,438	409,213
Sum of fixed costs	164,077	225,606	143,567	533,250
Profit/Loss	99,374	-82,282	-141,129	-124,037

Source: author's compilation

The results clearly show a pronounced seasonal imbalance. The high season generates a profit of €99,374, which is primarily attributable to high occupancy rates and sufficient energy consumption to cover fixed infrastructure costs. In contrast, the low season already shows a significant deficit, which expands further in the off-season. When all seasons are combined, the charging infrastructure causes an annual loss of approximately €124,037. This result highlights the structural vulnerability of charging infrastructure in highly seasonal tourist destinations. While peak periods can generate reasonable margins, longer periods of low utilization negatively impact annual profitability.

The results show that profitability is heavily dependent on capacity utilization and electricity procurement costs. Even moderate increases in electricity procurement prices or slight declines in demand can push the annual result further into the red. As a result, seasonal destinations face a structural conflict of objectives between ensuring sufficient charging capacity during peak periods and avoiding overinvestment, which leads to underutilization during the rest of the year.

In addition to the base scenario, sensitivity scenarios can be analyzed to illustrate how changes in key parameters affect financial results. For example, if the purchase price of electricity is reduced by 10% and selling prices are increased by 10%, the overall result becomes positive at €48,189.

5 Results

The model results clearly illustrate the structural challenges associated with expanding the infrastructure in highly seasonal tourism regions. The analysis of charging coverage shows a pronounced asymmetry between peak and off-peak times. In the high season, charging demand is close to available capacity. In contrast, the low season shows significant overcapacity.

From an economic perspective, this imbalance directly leads to financial risk. While sufficient contribution margins are achieved during the high season to cover fixed costs and generate seasonal profits, the low season and off-season remain structurally loss-making due to ongoing fixed infrastructure costs combined with low occupancy rates. As a result, the annual result is negative despite strong performance in the peak months.

These results highlight a fundamental trade-off: ensuring sufficient charging capacity to maintain service quality and visitor satisfaction during peak load times inevitably leads to underutilization during longer periods of low demand. Relying exclusively on private charging facilities (e.g., hotel-based charging options) seems unrealistic for meeting peak demand. At the same time, oversizing public infrastructure to eliminate seasonal bottlenecks can undermine economic sustainability. Although private charging infrastructure at accommodation facilities may cover a part of the demand, relying exclusively on private charging would require unrealistically high installation rates across all accommodation providers and would therefore not eliminate the need for public infrastructure. The model thus shows that seasonal tourist destinations face a double challenge: they must ensure reliable charging availability during the high season while also ensuring long-term profitability throughout the year.

From a practical perspective, the model can support destination managers and local authorities in evaluating different infrastructure sizing strategies and pricing models. It provides a transparent decision-support tool to balance service quality during peak periods with long-term economic sustainability.

6 Discussion

The results of this study highlight the structural tension between infrastructure adequacy and economic profitability in highly seasonal tourism regions. The model shows that ensuring sufficient charging capacity during peak periods inevitably leads to overcapacity and insufficient utilization during longer periods of low demand. This imbalance poses a strategic challenge for the management of tourist destinations and local decision-makers. Consequently, charging infrastructure planning in tourism regions cannot be treated solely as a technical infrastructure problem but must be integrated into broader regional development and mobility strategies. Simple corrective measures such as reducing the number of charging stations or increasing electricity prices are not necessarily viable solutions. Reducing infrastructure capacity can compromise service quality during peak season and potentially impact visitor satisfaction and the competitiveness of the destination. Conversely, significant price increases could deter electric vehicle users and conflict with overall sustainability goals. Instead, a more adaptable and data-driven approach seems appropriate. One possible strategy is to implement a phased infrastructure

development model in conjunction with continuous monitoring of user satisfaction and usage intensity. The collection of empirical data - for example, through user surveys, utilization tracking, and analysis of charging behavior - would enable evidence-based adjustments to the scope of the infrastructure and the charging mix (normal (AC) charging vs. fast (DC) charging). The preference structure between normal (AC) charging and fast (DC) charging requires special attention. Even though charging time may be less critical in a vacation context compared to everyday mobility, convenience and flexibility can still influence user satisfaction. Future research should therefore incorporate behavioral data to refine demand assumptions and better align infrastructure planning with actual usage patterns.

Ultimately, the results suggest that seasonal charging infrastructures should not be evaluated solely based on their short-term profitability. Rather, they must be understood as part of a broader location strategy that balances service reliability, sustainability goals, and long-term economic resilience. However, it should also be noted that the model presented contains numerous levers in the form of parameter values. An example scenario is considered to illustrate the sensitivity of the model:

- Halving the number of charging stations to 50 normal (AC) charging stations and 5 fast (DC) charging stations would have a positive effect on profitability, as the annual result would increase to €142,588. However, this would be at the expense of the charging coverage ratio, which would fall well below 100% in both the high and low seasons. For the peak season, charging coverage would be only 54% and process coverage only 58%.

The sensitivity example shows that although profitability can change significantly, the fundamental seasonal structural problem remains. The sensitivity examples once again demonstrate the performance of the model developed, namely the ability to translate changes in parameters directly into critical results in terms of meeting customer needs and profitability.

7 Conclusions

This paper develops and applies a structured modeling framework to assess the adequacy and cost-effectiveness of charging infrastructure in highly seasonal tourism destinations. By integrating a demand-driven charging coverage ratio with a partial

cost-benefit analysis, the model enables a comprehensive assessment of both technical capacity and financial sustainability. The case study shows a pronounced seasonal imbalance. While demand in the high season approaches capacity limits, longer periods of low demand, especially in the off-season, cause significant overcapacity and insufficient utilization. From an economic perspective, this structural asymmetry leads to a fragile business model in which profits in the high season are not sufficient to fully offset the fixed costs incurred in the low season.

The results highlight a fundamental dilemma for tourism regions: infrastructure must be dimensioned to ensure reliability and service quality during peak demand periods, but the same infrastructure can compromise annual profitability due to seasonal underutilization. The model therefore contributes to a more nuanced understanding of infrastructure planning in seasonal contexts and highlights the importance of incorporating demand modeling into economic assessments.

There are some limitations to consider. The model is based on scenario-based parameters, including assumptions regarding the proportion of electric vehicles, charging behavior, electricity procurement costs, and usage rates. Although these parameters are based on existing literature and current market data, deviations may occur in practice. Future research should validate and calibrate the model using empirical data from specific target locations, taking into account charging behavior patterns and dynamic pricing strategies. In addition, potential constraints of the local electricity grid infrastructure are not explicitly considered in the model and may influence the practical feasibility of large-scale infrastructure deployment.

Despite these limitations, the modeling framework provides a transferable analytical tool for destination managers and policymakers. It supports evidence-based decision-making regarding infrastructure sizing, seasonal planning, and long-term investment strategies. Given the increasing prevalence of electric mobility, such integrated approaches are becoming increasingly important to ensure both service reliability and economic resilience in regions dependent on tourism. The model can be easily adapted to other tourism regions by adjusting a limited set of input parameters.

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ASSESSING DISCLOSURE QUALITY OF WORKFORCE TRANSFORMATION UNDER ESRS S1: AN IRO–PATM ANALYSIS OF THE AUTOMOTIVE INDUSTRY

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The transformation of the European automotive industry through electrification and digitalisation is reshaping employment structures and skill requirements. Under the Corporate Sustainability Reporting Directive (CSRD) and the ESRS S1 standard (“Own Workforce”), companies are required to disclose workforce-related impacts within standardised sustainability reporting. However, it remains unclear whether these requirements foster substantive transparency or primarily result in formal compliance. This study examines the quality of workforce transformation disclosures by linking materiality diagnosis of impacts, risks and opportunities (IRO) with management operationalisation across policies, actions, targets and metrics (PATM). Based on a qualitative content analysis of sustainability reports from ten major European automotive manufacturers and suppliers, the study analyses whether identified transformation risks are translated into coherent management structures. The results reveal a structural asymmetry: workforce transformation is predominantly framed as a risk issue, while management responses are mainly communicated through operational measures. Formally codified policies and consistent target and metric systems remain weak. Differences between staff reductions and upskilling/reskilling indicate field-specific disclosure logics. Overall, integration between IRO diagnosis and PATM operationalisation remains partial. The study contributes by systematically analysing disclosure architecture and distinguishing between formal compliance and structural management integration.

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1 Introduction

The European automotive industry is undergoing a profound structural transformation driven by electrification, digitalisation and intensified global competition, requiring economic, environmental and social adjustments.

As one of the most employment-intensive industrial sectors in the European Union, the automotive industry is particularly affected, as these developments impact not only corporate structures but also broader labour market dynamics. In particular, ongoing job reductions and shifting skill requirements indicate that this transformation has far-reaching implications for job security and working conditions beyond technological change.

Against this backdrop, regulatory transparency requirements are gaining importance. Through the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), the European Union seeks to enhance the comparability, decision-usefulness and verifiability of sustainability information. The ESRS S1 (“Own Workforce”) social standard explicitly requires companies to disclose the impacts of their business activities on their own workforce. This places the social dimension of transformation, particularly employment risks, restructuring and training and reskilling initiatives, at the centre of external sustainability reporting.

The disclosure literature repeatedly suggests that regulatory requirements do not necessarily result in substantive transparency but may instead encourage symbolic or selective disclosure patterns (Dienes et al., 2016; Velte, 2023). In light of these developments, it remains unclear whether the first wave of CSRD-compliant reporting provides a robust basis for evaluating workforce-related transformation risks or primarily reflects formal compliance. In particular, systematic analyses integrating materiality diagnosis in terms of impacts, risks and opportunities (IRO) with operationalisation across policies, actions, targets and metrics have been lacking.

This study addresses this research gap by examining how companies in the European automotive and supplier industry report workforce-related transformation under ESRS S1. To this end, the analysis links materiality diagnosis (IRO) to a category-

based assessment of communicated management responses across policies, actions, targets and metrics (PATM). This approach enables a differentiated reconstruction of the internal disclosure architecture and allows for a systematic distinction between different levels of disclosure quality.

The results indicate a consistent disclosure pattern: the workforce is predominantly framed as a risk and compliance issue, whereas management responses are primarily communicated through operational programmes. In contrast, formally codified policies as well as systematic target-setting and key performance indicator (KPI) systems remain limited. Differences between workforce reduction and upskilling/reskilling emerge mainly in the degree of operational specificity rather than in the formal design. Additionally, qualitative differences become apparent in the linguistic framing of sensitive topics, suggesting strategic communication patterns that extend beyond purely formal transparency.

On this basis, the study makes several contributions to disclosure and sustainability research. First, it extends the literature on ESRS implementation by providing one of the first empirical analyses of social standard S1 in a transformation-intensive industry. Second, by combining the IRO and PATM perspectives, it develops an integrative analytical framework that systematically links materiality diagnosis and operationalisation, thereby rendering both dimensions analytically comparable. Third, the study complements the structural analysis of disclosure with a narrative perspective by examining how linguistic framing and communicative explicitness shape disclosure quality. Disclosure is thus conceptualised not merely as a question of scope, but as a multidimensional communication practice.

The article is structured as follows. Section 2 outlines the theoretical background and the current state of research. Section 3 describes the research design and methodological approach. Section 4 presents the empirical findings. Section 5 discusses the results and their implications. Section 6 concludes with a summary and an outlook.

2 Reporting Workforce Transformation: Conceptual Foundations

2.1 Workforce transformation in the automotive industry

The automotive industry is undergoing structural change that is less a form of incremental technological progress than a fundamental reorganisation of industrial value creation structures. Key drivers include the electrification of powertrains, regulatory decarbonisation targets, and the increasing software and digitalisation intensity of vehicles and production processes. Given the industry's substantial macroeconomic relevance accounting for approximately 7% of European gross domestic product and nearly 14 million direct or indirect jobs these developments generate significant cross-industry spillover effects (Cornet et al., 2023). Forecasts indicate that electric vehicles will account for nearly 60% of new registrations in Europe by 2030, thereby structurally displacing combustion engine technologies (International Energy Agency, 2025).

The lower technical complexity of electric drivetrains reduces labour-intensive manufacturing costs and shifts value creation from mechanical components towards battery, electronics, and software-based technologies. As a consequence, traditional stages of the supply chain lose relevance (Herrmann et al., 2020; Boquera-Rubio et al., 2025; Cornet et al., 2023). These structural transformations are accompanied by corresponding shifts in employment structures. In Germany, nearly every second job in the automotive industry depends directly on the combustion engine; by 2030, up to 215,000 employees could be affected. At the same time, knowledge- and technology-intensive functions are gaining importance (Falck et al., 2021; Herrmann et al., 2020).

At the company level, structural change manifests itself in strategic adjustments to human resource management (HRM). The declining demand for mechanical manufacturing and assembly skills is associated with reduced staffing requirements and restructuring in traditional occupational fields, while new competency demands emerge in software, electronics, and data-driven functions. Companies respond by reorganising their HR systems, recruiting externally, and relocating knowledge-intensive development and IT activities across global value chains.

At the same time, reskilling, upskilling, and internal mobility gain importance as central instruments of strategic HRM, enabling the targeted reconfiguration of skills profiles. In the context of transformation, a conceptual distinction must be drawn between upskilling and reskilling. Upskilling refers to the further development of existing competencies within related job profiles, whereas reskilling denotes the acquisition of new qualifications for altered or alternative functional areas (cf. Achillas & Iosifidou, 2024; Krzywdzinski & Jo, 2020). Both strategies are widely regarded in the literature as key instruments for managing technology-induced shifts in skill requirements.

Empirical studies and case analyses in the automotive industry confirm this combination of functional reallocation, targeted skills development, and selective staff reductions (Achillas & Iosifidou, 2024; Krzywdzinski & Jo, 2020; Niyaz et al., 2025). However, the effectiveness of these adjustments depends largely on employees themselves. As carriers of organisation-specific knowledge and learning capacity, they constitute a central prerequisite for organisational adaptability. Human resource policy therefore addresses not only efficiency considerations but also assumes a strategic management dimension.

In labour-intensive industries such as the automotive sector, this constellation generates a structural tension between productive and social risk dimensions. While employees enable transformation processes, staff reductions, reskilling requirements, and job insecurity simultaneously create social risks, reputational pressures, and heightened legitimization expectations from stakeholders. Workforce transformation thus extends beyond a question of operational efficiency and becomes an issue of organisational governance and legitimacy (Mukhuty et al., 2022).

This ambivalence leads to increased accountability towards external stakeholders. Companies are increasingly expected to render the social impacts of their transformation strategies transparent and to justify them vis-à-vis different stakeholder groups. The relevant stakeholders extend beyond capital market actors: employees and regionally affected communities are directly exposed to staff reductions, changing qualification requirements, and location decisions, and therefore have a legitimate claim to information. Reporting on staff reductions, qualification measures, and job security thus constitutes not merely documentation

but also an instrument of legitimization, trust-building, and the social embedding of transformation processes.

However, empirical studies indicate that CSR and reporting practices in restructuring contexts often serve primarily symbolic legitimization functions without ensuring comprehensive accountability (Mäkelä et al., 2010; Cornea et al., 2021). At the same time, the European regulatory framework institutionalises explicit participation and information rights for employee representatives through mandatory sustainability reporting under the CSRD/ESRS regime, thereby expanding the scope of stakeholders addressed beyond investor-oriented transparency requirements (Vitols et al., 2023).

2.2 Regulation and transparency under ESRS S1

The increasing social and employment-related risks associated with industrial transformation intensify information asymmetries between companies and their stakeholders. Employees, investors, and regionally affected communities in particular often possess only limited and selective information regarding staff reductions, qualification strategies, or long-term employment effects. Against this backdrop, regulation can be conceptualised as a governance instrument that institutionalises accountability through mandatory disclosure and renders organisational decisions transparent and verifiable to stakeholders.

From a disclosure and accountability perspective, transparency is not merely the provision of information but a mechanism that shapes organisational behaviour. Standardised reporting seeks to ensure comparability and decision-usefulness, thereby making organisational actions accessible to public scrutiny (Healy & Palepu, 2001; Roberts, 2009). Mandatory disclosure can thus be understood as an institutional instrument that generates expectation pressure and fosters organisational adaptation to prevailing social norms. Empirical evidence further indicates that mandatory sustainability reporting increases the visibility of social impacts and, under certain conditions, may contribute to changes in organisational practices (Christensen et al., 2021).

With the Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS), this transparency logic is explicitly extended to social and employment-related dimensions. In particular, ESRS S1 (“Own Workforce”) establishes systematic reporting requirements concerning working conditions, qualifications, job security, and work-related risks and impacts. The regulatory framework thereby broadens the scope of addressees of sustainability reporting beyond capital market-oriented information interests and anchors explicit accountability obligations towards employees and their representatives. Sustainability reporting thus constitutes not only investor-oriented disclosure but also an instrument of stakeholder-oriented governance (Vitals et al., 2023).

However, this regulatory transparency logic presupposes that disclosed information reliably reflects organisational practices and induces substantive changes in organisational behaviour. Whether this assumed link between formal disclosure and operational practice holds empirically remains contested in organisational theory and provides the point of departure for the subsequent discussion of organisational responses to disclosure requirements.

2.3 Organisational responses to disclosure

The regulatory expectation that standardised disclosure requirements create substantive transparency and comparability presupposes a close alignment between reported information and actual organisational practices. However, neo-institutional organisational theory fundamentally questions this assumption. Empirical studies on the institutional embeddedness of organisations demonstrate that external requirements are often adopted through formal structures without corresponding implementation in operational routines. This pattern, referred to as decoupling, enables organisations to signal regulatory compliance and secure legitimacy while core processes remain largely unchanged (Meyer & Rowan, 1977; Bromley & Powell, 2012). Disclosure requirements may therefore foster symbolic compliance rather than substantive changes in organisational practices.

Applied to sustainability and workforce reporting, this perspective suggests that compliance with regulatory requirements does not necessarily coincide with a comprehensive and reliable representation of actual employment effects. Instead, reports may primarily serve to demonstrate conformity with regulation and thus

function as signals of legitimacy rather than as instruments of accountability. Empirical research in the context of restructuring and downsizing further indicates that CSR and accounting information fulfil distinct legitimising functions: on the one hand, they are employed rhetorically to justify corporate decisions (Mäkelä et al., 2010); on the other hand, they may strategically contribute to stabilising organisational legitimacy and mitigating negative performance effects among remaining employees (Cornea et al., 2023).

This loose coupling between formal disclosure and operational practice manifests itself at the level of communication. Disclosure is not merely the technical transmission of information but a selective and malleable process of representation in which content is chosen, framed, and evaluated.

Research on impression management conceptualises reporting as an instrument for shaping external perceptions and securing organisational legitimacy (Bolino et al., 2008). Studies on narrative and voluntary disclosure further demonstrate that companies use discretionary information to emphasise positive performance while downplaying or obscuring problematic developments (Merkel-Davies & Brennan, 2007). Such practices manifest in selective presentation strategies, including increased textual complexity, aggregation of sensitive key figures, or the omission of critical information (Courtis, 2004). Sustainability and CSR reports in particular often contain symbolic or façade-like elements that signal conformity without providing substantive accountability (Boiral, 2013; Cho et al., 2015). Employment-related issues are especially sensitive in this regard, as layoffs, site closures, or skill losses can trigger immediate social and political reactions.

This communicative discretion is particularly pronounced in employment-related disclosure. Social and work-related issues can often only be captured to a limited extent through standardised, quantitatively robust key performance indicators and therefore rely more heavily on qualitative or context-dependent measures. The assessment of working conditions, skills development, or job security consequently remains interpretative and narrative in character, which constrains comparability while expanding discretionary scope for presentation (Nwagwe et al., 2022). Research on sustainability reporting indicates that such conditions favour narrative accounts and foster symbolic or ceremonial reporting elements that are only loosely coupled to operational practices (Boiral, 2013; Cho et al., 2015; Michelon et al.,

2015). Workforce disclosure is therefore structurally more susceptible to selective or discretionary design.

In sum, the interplay of decoupling and strategic communication suggests that regulatory disclosure requirements may systematically diverge from substantive transparency and function as organisational instruments for managing institutional expectations. Reporting obligations therefore not only generate information flows but also create structural scope for selective and discretionary presentation. Against this backdrop, analytical approaches are required that assess not merely the formal presence of disclosures but also their substantive content, internal coherence, and communicative framing. The following section develops an integrated analytical framework for this purpose.

2.4 Analytical frame of reference: IRO-PATM as an integrated perspective

Given the limited informative value of purely formal disclosure requirements, an integrated analytical framework is required that systematically links regulatory requirements, organisational decision-making processes, and communicative presentation practices in order to assess the substance and quality of workforce disclosure. The structures of the double materiality analysis (DMA) embedded in the European Sustainability Reporting Standards (ESRS), operationalised through the categories of impacts, risks, and opportunities (IRO), together with the policy–action–target–metric (PATM) logic, constitute the conceptual core of this framework.

The DMA functions as a normative mechanism for selecting sustainability matters subject to reporting requirements. A topic is deemed material if it involves significant actual or potential impacts on people or the environment (impact materiality) or gives rise to financial risks or opportunities that may affect the company’s financial position (European Commission, 2023, ESRS 1, paras. 28–35, 44–53). Materiality is determined through the structured identification and assessment of IRO, including an evaluation of both severity and likelihood of occurrence (European Commission, 2023, ESRS 1, paras. 55–59).

For ESRS S1 (“Own Workforce”), this implies that reporting requirements do not derive directly from the standard itself but arise contingently from the upstream IRO analysis (European Commission, 2023, ESRS S1, para. 3). The scope of workforce disclosure must therefore be inferred from the documented materiality assessment. The DMA/IRO logic thus translates regulatory requirements into organisational assessment decisions and defines the thematic selection logic of reporting.

While the DMA/IRO determines which work-related topics are classified as material, the PATM logic structures their communicative operationalisation. ESRS 2 requires disclosures on policies, actions, targets, and metrics for each material sustainability topic (European Commission, 2023, ESRS 2, paras. 60–80). This minimum disclosure requirement establishes a systematic link between normative commitments, operational measures, and performance indicators, thereby connecting strategic intent with implementation and measurable outcomes. Disclosure must explicitly refer to previously identified material topics (European Commission, 2023, ESRS 2).

The MDR-based architecture of the ESRS is structurally compatible with internal management and control systems and may enhance the traceability between strategic commitments and reported outcomes. However, formal coherence does not ensure substantive integration. The linkage of policies, actions, targets, and metrics can be presented in a formally compliant manner while remaining internally fragmented—for instance through unspecified targets, weakly operationalised measures, or key figures lacking a discernible causal connection. In such cases, the disclosed management architecture remains structurally disaggregated, and the link between the reported governance structure and the depiction of operational implementation is only loosely coupled.

Another critical aspect concerns the substantive linkage to the identified IROs. The PATM disclosures may present general elements of human resource management without explicit reference to the work-related risks or opportunities classified as material. In such cases, the reporting fulfils the formal structural requirements; however, its content remains disconnected from the underlying materiality assessment and thereby loses thematic specificity.

Within the integrated analytical framework, the combination of DMA/IRO analysis and PATM assessment fulfils a dual evaluative function: the DMA/IRO determines the material relevance of work-related aspects, while the PATM enables an assessment of their implementation consistency. High-quality workforce disclosure is accordingly characterised by the consistent translation of identified material IROs into policies, their operationalisation through concrete measures, their substantiation by quantified targets, and their measurability through appropriate key performance indicators.

In this article, disclosure quality is conceptualised not merely as scope or formal completeness but as the degree of substantive specificity with regard to identified material IROs and their structural integration. It is assessed by the extent to which identified material IROs are consistently translated into policies, operationalised through concrete measures, substantiated by quantified targets, and rendered measurable through indicators with a discernible causal linkage.

Despite the increasing institutionalisation of sustainability reporting through standardised frameworks such as the European Sustainability Reporting Standards (European Commission, 2023), research has so far paid limited attention to the extent to which labour-related disclosures exhibit quality in terms of linkage to identified IROs and structural integration. In particular, it remains unclear whether social disclosures are systematically derived from identified material impacts, risks, and opportunities and coherently operationalised within the policy–action–target–metric logic, or whether they predominantly reflect general human resource management practices without a discernible connection to the documented materiality assessment.

Thus, it remains empirically unclear to what extent workforce disclosure not only fulfils formal compliance requirements but also achieves substantive transparency in terms of content specificity and structural integration. This research gap constitutes the point of departure for the present study.

Against this backdrop, the study examines the extent to which workforce transformation is not only formally disclosed within the ESRS framework but also presented in a substantively specific and structurally integrated manner. The analysis focuses on two analytically interrelated levels: the framing of workforce-related

issues within the IRO analysis and their operationalisation within the PATM structure.

This gives rise to the following research questions:

RQ1:

How is workforce transformation identified as material and articulated in substantive terms through the double materiality analysis (DMA) via impacts, risks, and opportunities (IRO)? This question addresses the problem definition level of reporting and examines whether transformation-related employment dynamics are identified as material impacts, risks or opportunities and whether they are conceptualised in a risk- or value-oriented manner.

RQ2:

How are work-related transformation areas operationalised within the policy–action–target–metric (PATM) structure, and what patterns of formalisation and quantification can be observed? This question focuses on the structural configuration of the managerial response, in particular the translation of transformation-related issues into policies, measures, targets, and key performance indicators, as well as their explicit linkage to identified IROs.

RQ3:

To what extent is workforce transformation presented in reporting as a materially specific and structurally integrated management context? This integrative question combines problem framing and operationalisation and examines whether a coherent, IRO-related linkage can be identified between the materiality analysis and the PATM structure.

3 Methodology

3.1 Research design

The study adopts a two-stage qualitative, document-based research design for the systematic examination of sustainability reporting in accordance with ESRS S1 (“Own Workforce”). The objective is not to evaluate regulatory compliance or normative adequacy, but to analyse structural configuration and the integration logic between materiality assessment and operationalisation within the PATM framework.

To this end, a comparative reconstruction of the structural architecture, degree of transparency, and content framing of the disclosed information is undertaken. Particular emphasis is placed on the treatment of transformation-related employment and qualification requirements and, in this context, on the linkage between materiality diagnosis (IRO) and its operational translation within the PATM structure.

3.2 Data basis and sample

The study concentrates on the European automotive and supplier industries. These industries are characterised by profound transformation dynamics, particularly electrification, digitalisation and the reconfiguration of global value chains (Cornet et al., 2023; International Energy Agency, 2025), which exert substantial effects on employment structures and qualification requirements. The industry-specific focus narrows the analytical scope to a comparatively homogeneous transformation context and thereby enhances the comparability of disclosure architectures and operationalisation logics.

The empirical basis comprises published sustainability and annual reports from companies within this sector that are classified as CSRD/ESRS-compliant (Sustainability Reporting Navigator, 2025). These formal disclosure documents constitute the primary unit of analysis, as they reflect the externally communicated representations of management approaches and operationalisation structures. The object of investigation is thus not internal organisational practices, but exclusively the reported disclosures.

The sample was determined through a multi-stage, theory-driven selection process. The point of departure was a reporting overview provided by the Sustainability Reporting Navigator (Sustainability Reporting Navigator, 2025), a research infrastructure established within the framework of the transregional Collaborative Research Centre TRR 266 “Accounting for Transparency”, funded by the German Research Foundation (DFG). Based on this overview, 554 CSRD-compliant reports across industries were identified as of the cut-off date of 20 June 2025. From this population, companies belonging to the European automotive manufacturing and supplier industries were extracted for further screening. To reduce structural heterogeneity, the sample was restricted to large, listed and internationally operating

companies with more than 50,000 employees. This restriction is grounded in empirical evidence indicating that company size, governance structures and available organisational resources exert a substantial influence on the structure and degree of differentiation of non-financial reporting (Radu et al., 2023; Kosi et al., 2024; Leal Filho et al., 2025).

The company sample comprises ten large European automotive manufacturers and suppliers subject to CSRD reporting requirements. An overview of the sample characteristics is presented in Table 1.

Table 1: Sample of Automotive Manufacturers and Suppliers Included in the ESRS S1 Disclosure Analysis (Reporting Year 2024)

Company	Industry	Revenue (€ m)	Employees	HQ Country	Report Type	ESRS S1 Section (pp.)
BMW	Automotive manufacturer	142,380	158,441	Germany	Annual Report	163– 174
Continental	Automotive supplier / Tires	39,719	183,358	Germany	Annual Report	170– 188
Forvia	Automotive supplier	26,974	150,000	France	Universal Registration Document	121– 143
Mercedes- Benz	Automotive manufacturer	145,600	175,264	Germany	Annual Report	196– 212
Michelin	Automotive supplier / Tires	27,200	129,832	France	Universal Registration Document	262– 271
Renault	Automotive manufacturer	56,200	98,636	France	Universal Registration Document	181– 203
Schaeffler	Automotive & industrial supplier	18,188	115,937	Germany	Annual Report	88–99
Stellantis	Automotive manufacturer	156,878	248,883	Netherlands	Sustainability Statement	64–84
Valeo	Automotive supplier	21,492	95,284	France	Universal Registration Document	260– 281
Volkswagen	Automotive manufacturer	324,700	614,082	Germany	Annual Report	362– 391

Note. Revenue figures are reported in EUR million for fiscal year 2024. Employee data reflect total headcount as disclosed in the respective corporate reports. The ESRS S1 section refers to the page range analyzed for disclosures on “Own Workforce.” The complete company-level dataset, coding framework, and detailed ESRS S1 disclosure mappings are provided in the Online Supplementary Material (Appendices S1–S3).

This number of cases enables an in-depth qualitative document analysis while allowing for structured cross-case comparison. The analysis focuses on the most recent reporting cycle available at the time of data collection (reporting year 2024).

3.3 Analytical approach

The content analysis is conducted in two stages, document-based and applies a qualitative structuring approach, supported by a standardised extraction and coding scheme. In a first step, it is reconstructed whether employment-related issues are classified as material and on which justificatory grounds this classification is based. Subsequently, the reported governance and operationalisation approaches implemented to address these issues are systematically examined.

3.3.1 Step 1: DMA/IRO analysis

The first step analyses whether and in which form companies classify transformation-related impacts on their own workforce as material within the framework of the double materiality assessment (DMA).

The objective is to reconstruct the problem diagnosis documented in the reports, i.e. to identify which labour market- and qualification-related impacts, risks and opportunities are recognised, prioritised and communicated as material in the context of ESRS S1. In addition, the underlying content framing (e.g. risk-oriented, compliance-oriented or value-creation-oriented) in which the identified IROs are embedded is systematically captured.

Step 1 addresses the problem-definition and assessment level (“Why is the issue material?”) and establishes the analytical foundation for the subsequent examination of the reported response structures.

To this end, company-specific IRO analyses are conducted on the basis of a standardised questionnaire (F1–F11), which operationalises the core disclosure requirements of ESRS S1. In particular, the following dimensions are addressed:

- materiality classification of labour market-related topics,
- addressed sub-topics,

- identified impacts, risks and opportunities,
- scope and affected stakeholder groups,
- methodological and organisational anchoring of the analysis.

For each question, a three-level evidence rating (explicit, implicit, not mentioned) is assigned. In addition, a factual paraphrase, a verbatim quotation and a precise page or section reference are documented. The evaluation is strictly confined to documented statements; interpretative extensions or normative assessments are deliberately excluded. The results are recorded in a standardised, structured extraction table and systematically reviewed for completeness and consistency by means of a predefined checklist.

Building on the reconstructed materiality assessment and problem diagnosis, the second step examines how the issues classified as material are addressed within the reporting architecture. To this end, the disclosed policies, actions, targets and metrics are systematically captured in accordance with the PATM model and analysed with regard to their degree of specificity and their structural interdependencies. In addition, the analysis assesses whether and in which form PATM elements explicitly refer to previously identified impacts, risks or opportunities in order to determine the degree of explicit IRO linkage between materiality diagnosis (DMA/IRO) and operationalisation (PATM).

3.3.2 Step 2: PATM- analysis

The analytical focus is directed at the core components of a management approach structured in accordance with the PATM model:

- Policies (normative guidelines and regulations),
- Actions (concrete programmes of measures),
- Targets (operationalised target values),
- Metrics (indicator-based performance and impact indicators).

The PATM analysis concentrates on two central dimensions of workforce transformation that appear particularly salient in the context of technological and organisational upheaval within the European automotive industry: workforce

reductions and upskilling and reskilling initiatives. Both dimensions are intrinsically linked to the transformational capacity of companies, yet differ substantially with regard to their strategic embedding, communicative sensitivity and anticipated disclosure practices. Workforce reductions are typically associated with heightened reputational sensitivity and potentially conflictual stakeholder effects, particularly in relation to employee representatives, trade unions and political actors.

Substantive reporting in this domain extends beyond the mere disclosure of aggregate employee figures and encompasses comprehensible information on underlying governance principles, decision-making and process logics, social mitigation measures and, where applicable, defined target horizons and corresponding metrics. These characteristics render workforce reductions particularly suitable for identifying the limits and inherent tensions of disclosure depth under ESRS S1, as the differentiation between symbolic reporting and substantive transparency proves especially demanding in this field.

For each of the two workforce transformation domains, relevant text passages, levels of evidence, paraphrases and precise references are systematically extracted. The analysis thereby reconstructs the reported management and action logic underlying these domains. Both topics are treated as distinct analytical blocks and subsequently subjected to a comparative examination in order to identify field-specific patterns of structural integration and disclosure depth.

3.4 Coding and operationalisation

Within the framework of a qualitative content analysis with quantitative evaluation, deductive assessment and consensus coding, a supplementary analytical coding stage was implemented in addition to the structured extraction of PATM components in order to systematically capture the degree of concretisation and specification of the reported workforce measures.

Methodologically, this approach is grounded in rule-based qualitative content analysis in accordance with Schreier (2012), which provides for the deductive application of predefined categories and explicit decision rules.

The coded characteristics are subsequently subjected to a quantitative evaluation in order to render patterns of formalisation and structural integration systematically comparable across cases.

The analytical procedure was conducted in two stages. In the first stage, the identified text passages were qualitatively coded and classified with regard to their transformation relevance. Statements exhibiting a clear reference to transformation-specific workforce aspects were coded as concrete, whereas general or purely descriptive statements lacking explicit transformation relevance were coded as non-concrete. This deductive coding logic was applied consistently across all categories of the PATM model. In the second stage, the coded passages were quantitatively assessed using the SRQ methodology proposed by Elaigwu et al. (2024). The applied scale ranges from 0 to 3: a value of 3 denotes report components containing both qualitative and quantitative information; 2 indicates disclosures including quantitative or monetary details; 1 captures general or exclusively qualitative statements; and 0 reflects the complete absence of relevant information.

The aggregated score is calculated by summing the scores assigned across all PATM categories. This aggregation serves exclusively the descriptive structuring and comparative classification of disclosure patterns. The underlying scale is ordinal in nature; accordingly, aggregated values are not interpreted as interval-scaled metrics and are not employed to assess the performance of individual companies. Rather, the SRQ functions as an instrument for the structural aggregation of the ordinally coded PATM dimensions and enables a comparative representation of relative disclosure patterns within the sample.

To ensure intersubjective traceability, coding was conducted using a parallel multiple-coding procedure grounded in the principles of multi-rater content analysis (Krippendorff, 2019). Three independent coders evaluated the relevant text passages on the basis of an explicit coding guide. Deviations were addressed within a structured consensus procedure involving additional peers and resolved through mutual agreement. A formal statistical reliability coefficient was not calculated, as the primary objective was the harmonisation of interpretative coding decisions through a structured consensus procedure.

To further validate the coding results, an AI-supported comparative assessment was conducted. Automatically generated text analyses were systematically compared with the manually developed codes in order to identify potential omissions or inconsistencies. Any discrepancies identified were subsequently reviewed manually and, where necessary, adjusted. The AI did not function as an independent evaluative authority but rather as a technical support instrument for the systematic review of the documents.

The coded content from both analytical stages is subsequently integrated into a unified evaluation framework and subjected to a comparative analysis. To this end, the extracted information is systematically recorded in a predefined comparison matrix (company $\times$ analysis categories). This matrix ensures a consistent comparison of the documented evidence at both the individual case level and across categories, thereby enabling a structured cross-case analysis of framing patterns, operationalisation logics and structural integration. The matrix is populated exclusively on the basis of the coded text passages; external data sources, supplementary scores or external rankings are not incorporated.

The evaluation follows a structured and comparative logic. By systematically contrasting the codes across cases, recurring patterns, divergences and characteristic features of reporting are identified in order to typologically characterise disclosure practices and communicated operationalisation approaches. The objective is neither to assess performance nor to establish rankings of individual companies. This approach enables a transparent and replicable analysis of reported disclosure and operationalisation logics, while refraining from deriving conclusions regarding the actual performance or effectiveness of the underlying measures.

3.5 Quality assurance and limitations

To ensure transparency and traceability, all coding decisions are documented in accordance with predefined rules and substantiated by standardised extraction tables and complete evidence documentation. The coding guidelines, evaluation logic and central extraction tables are provided in the Appendix S2.

The applied 0–3 scale is ordinal in nature. Aggregated values are interpreted exclusively in a descriptive sense and serve to facilitate a structured comparison of relative disclosure patterns; they are not conceived as metric quality measures or standardised performance indices.

Given the small and industry-specific sample, dimension-specific aggregate indicators within the individual transformation fields are not calculated.

Aggregated mean values are employed exclusively for cross-field comparisons and serve to classify structural patterns, but not to assess the performance of individual companies.

Accordingly, the generalisation of the findings to other industries or institutional contexts is only possible to a limited extent. It should further be emphasised that the analysis is confined exclusively to disclosed report content. No conclusions can be drawn regarding the actual design, implementation or effectiveness of internal management and control practices. Accordingly, the findings pertain to reported structures and communicated management logics rather than to observable organisational practices.

Detailed company-level data, coding criteria, and ESRS S1 disclosure mappings are provided in the Online Supplementary Material (Appendices S1–S3).

4 Empirical results

4.1 Overview of the sample and data basis

The empirical analysis comprises ten sustainability and annual reports of large, listed companies within the European automotive and supplier industry. Detailed information on the sample selection, data basis and reporting cycles is provided in Section 3; an overview of the examined companies is presented in Appendix S1.

4.2 Results Step 1: DMA/IRO – Materiality and problem diagnosis

The first stage of the analysis examines how workforce-related issues are identified and substantively framed within the context of the double materiality assessment (DMA) (see Section 3.3.1). The following section presents three key findings: (1) materiality recognition, (2) risk-oriented framing, and (3) thematic coverage.

The comparative results are presented in Appendix S3 and discussed below with reference to the central findings. As evidenced by Table C1, all examined companies classify workforce-related issues as a material sustainability matter. Materiality is predominantly communicated explicitly, for instance through dedicated ESRS S1 sections or clear labelling within materiality overviews. Differences arise less in formal recognition than in the substantive delineation of the underlying impacts, risks and opportunities.

Individual companies explicitly articulate transformation-related risks. For instance, Schaeffler refers to socially responsible workforce reductions in the context of transformation (p. 95), while Stellantis identifies shifts in skill profiles and potential job losses resulting from technological transformation as material risks (p. 22).

These examples illustrate the variance in both the scope and the depth of risk specification.

Taken together, the justification of materiality is clearly dominated by risk- and impact-oriented considerations. The identified IROs primarily relate to work-related matters, including occupational health and safety, human rights risks, labour disputes, as well as employment- and qualification-related transformation risks.

This emphasis is reflected both quantitatively in the number of reported impacts and risks and qualitatively in their substantive framing (see Appendix S3). By contrast, explicitly disclosed opportunities remain comparatively rare and are frequently articulated in general or non-specific terms.

Thematic coverage within ESRS S1 is broad. Almost all companies address multiple sub-dimensions—such as working conditions, occupational health and safety, qualifications, equal treatment and social dialogue—and formally delineate the scope of their own workforce. Differences arise primarily with regard to the level of detail and the systematic inclusion of distinct employee groups.

From a methodological perspective, the DMA is implemented in a formally consistent manner across cases. All companies explicitly refer to double materiality and apply a structured IRO logic. Variations become apparent in the depth of

methodological design and in the extent to which governance and risk management structures are integrated.

In summary, a consistent pattern becomes apparent: the workforce is formally established as a material topic and methodologically embedded, yet predominantly conceptualised through a risk-oriented lens. Strategic or value-creating interpretations of human capital, by contrast, remain secondary. The problem diagnosis thus follows a largely defensive and compliance-oriented logic.

Whether this framing is translated into coherent governance and action structures cannot be determined at this stage. The following section therefore examines how identified IROs are operationalised within the PATM framework.

4.3 Results of step 2: PATM – management and response level

4.3.1 In-depth analysis: Staff reductions

The evaluation reveals a generally weakly formalised disclosure pattern within the transformation field of workforce reductions. Table 2 summarises the standardised assessment across the four PATM dimensions. It provides a comparative overview of disclosure patterns across all sampled companies.

Table 2: PATM analysis results for staff reductions

Company	Policy (0-3)	Action (0-3)	Target (0-3)	Metric (0-3)	PATM total	Disclosure excerpt/page
Forvia	0	1	3	3	7	p. 129, 137, 140
Valeo	0	3	0	2	5	p. 260, 263, 276, 278, 279
Stellantis	0	1	0	2	3	p. 22, 69
Mercedes	0	3	0	0	3	p. 200, 201
Michelin	0	0	0	2	2	p. 269, 271
VW	0	1	0	0	1	p. 364, 367, 378
Schaeffler	0	1	0	0	1	p. 89, 94, 97
Continental	0	1	0	0	1	p. 171, 177, 184
Renault	0	0	0	0	0	p. 199
BMW	0	0	0	0	0	p. 163, 166, 167

Note. Standardised PATM scoring (0–3) derived from the author’s analysis of the companies’ 2024 sustainability reports.

Policies.

None of the examined companies disclose explicit, company-wide policies governing workforce reductions; accordingly, a policy score of 0 was assigned consistently across cases (see Table 2). Although isolated references to strategic workforce planning or transformation programmes are provided, these do not satisfy the criteria of formalised regulations with clearly defined procedures or binding minimum standards.

BMW refers to “long-term workforce planning” without specifying binding guidelines (p. 163), while Mercedes-Benz formulates general transformation objectives within its “Re-Shape” programme but does not outline standardised regulations for workforce reductions (p. 200). Overall, the reporting remains at a programmatic and descriptive level; a formalised policy architecture is not discernible.

Actions.

Disclosure in the area of workforce reductions primarily occurs at the level of operational measures. Seven of the ten companies report restructuring or workforce reduction initiatives, although the degree of specification varies considerably. In some cases, specific arrangements are referenced, such as temporary employment protection commitments (Mercedes-Benz, p. 201), whereas other companies address restructuring only indirectly within broader transformation programmes (e.g. Michelin, p. 269). Compared to the complete absence of a policy dimension, the action dimension is more prominently represented, yet remains structurally inconsistent.

Targets.

The target dimension remains clearly underdeveloped within the sample. Explicit and measurable targets are disclosed only in isolated cases. Forvia specifies concrete restructuring targets within its “EU Forward” plan and complements these with quantitative information, such as the number of employees affected and the planned duration of the programme (p. 129).

In the remaining cases, specific target values or quantified target systems are absent, such that no coherent target architecture can be identified.

Metrics.

Only four companies disclose quantitative indicators relating to workforce reductions. In some instances, differentiated information on employment trends or regional adjustments is provided (e.g. Forvia, pp. 137–140). In the majority of cases, however, such metrics are absent, thereby limiting comparability. Explicit linkages to previously identified transformation-related IROs remain rare.

Interim conclusion regarding workforce reductions

In the transformation field of workforce reductions, the PATM profile thus appears structurally unbalanced: while operational measures are reported with relative frequency, formal policies are entirely absent; targets and metrics remain selective and inconsistent. Disclosure is predominantly reactive and operational, with no discernible structural integration along the PATM logic.

4.3.2 In-depth analysis: Upskilling and reskilling

Disclosures relating to upskilling and reskilling measures exhibit a PATM profile that differs markedly from that observed in the field of workforce reductions (see Table 3).

The transformation field of upskilling and reskilling exhibits a heterogeneous PATM profile. While formal policies are documented only in isolated cases, measures and targets are explicitly articulated in several instances and, in part, complemented by quantitative indicators. The aggregated values vary considerably across companies and indicate differing degrees of structural integration and specification within the disclosed information.

Table 3: PATM analysis results for upskilling and reskilling

Company	Policy (0-3)	Action (0-3)	Target (0-3)	Metric (0-3)	PATM total	Disclosure excerpt/page
Stellantis	0	3	3	3	9	p. 64, 83, 84
VW	0	3	3	0	6	p. 375
Valeo	0	2	2	2	6	p. 264, 267, 275, 277, 280
BMW	1	1	2	2	6	p. 164, 169
Mercedes	1	1	3	0	5	p. 198, 201, 202
Michelin	1	3	0	0	4	pp. 267–270
Renault	0	1	2	0	3	p. 186, 190, 192, 194
Schaeffler	0	1	0	0	1	p. 89, 94, 96
Continental	0	1	0	0	1	p. 171, 176
Forvia	0	1	0	0	1	p. 133, 134

Note. Standardised PATM scoring (0–3) derived from the author’s analysis of the companies’ 2024 sustainability reports.

Policies.

The policy dimension remains comparatively weak within the transformation field of upskilling and reskilling. Seven of the ten companies do not disclose explicit, standalone policy frameworks; only three embed corresponding content within overarching strategies or guidelines. In some instances, relevant aspects are situated within general occupational health and safety objectives (e.g. Michelin, p. 267) or incorporated into the broader human resources strategy (e.g. Mercedes-Benz, pp. 198–200), without clearly defined and formalised policies being articulated.

Accordingly, an independent and systematically structured policy architecture is discernible only in isolated cases.

Actions.

The action dimension is consistently pronounced within the transformation field of upskilling and reskilling. All examined companies disclose qualification or training measures, although the majority report initiatives described in general terms (score 1). Only a limited number of companies document more structured programmes characterised by clearly defined measures, specified target groups or quantitative information. The observed differences relate primarily to the level of specification: while some companies address qualification measures in a comparatively generic manner (e.g. Renault, p. 192), others report structured programmes with more concrete design features (e.g. Stellantis, p. 84). In sum, this indicates a broadly

developed action dimension that remains heterogeneous in terms of specificity and degree of formalisation.

Targets.

The target dimension exhibits a differentiated profile within the transformation field of upskilling and reskilling. Six of the ten companies disclose explicit targets for qualification and training measures, whereas four do not report measurable target specifications. Three companies articulate clearly quantified and time-bound target values (score 3). This distribution results in a bifurcated pattern, distinguishing between concretely developed target architectures and purely measure-oriented representations lacking explicit target definitions.

Metrics.

In contrast, the metric dimension remains comparatively underdeveloped. Seven of the ten companies do not disclose explicit quantitative indicators relating to qualification or further training measures. Three companies provide corresponding metrics, with one case exhibiting a differentiated, multidimensional presentation of indicators including temporal references (e.g. Stellantis, p. 84). Overall, the disclosure of metrics is concentrated among a limited number of companies and does not reflect a broadly institutionalised or systematic approach.

Interim conclusion regarding upskilling and reskilling

Across cases, upskilling and reskilling exhibit a heterogeneous PATM profile that is, in certain cases, more structured than that observed in the transformation field of workforce reductions. While measures are consistently disclosed and targets are specified in several instances, formal policies and a coherent system of indicators remain limited. Disclosure is thus predominantly programme- and activity-oriented rather than rule-based or data-integrated.

Compared to workforce reductions, stronger linkages between problem diagnosis and target systems can occasionally be observed; however, consistent structural integration across all PATM dimensions is not achieved.

4.3.3 Asymmetric integration patterns of workforce transformation

For cross-field consolidation, an additive sum score (SRQ) is calculated as the aggregate of the four PATM dimensions (range: 0–12); standardisation (SRQ%) is applied exclusively for descriptive comparability.

Table 4: Aggregated PATM characteristics and additive sum score (SRQ) by transformation field

Transformation field	Policy Ø	Action Ø	Target Ø	Metric Ø	SRQ Ø (0–12)	SRQ %
Staff reduction	0	1.1	0.3	0.9	2.3	19
Upskilling & reskilling	0.3	1.7	1.5	0.7	4.2	35

Note. Values represent the author's own calculations based on the PATM scoring results. SRQ = additive sum of the four PATM dimensions (range: 0–12). SRQ% = SRQ/12 and reported for descriptive comparability.

The aggregated comparison shows clearly different disclosure profiles. In the transformation field of staff reductions, the average values are low in all dimensions; policies and target and key figure elements in particular are hardly pronounced, while measures are only documented to a limited extent. Upskilling and reskilling, on the other hand, achieve higher values in the dimensions of actions and targets, which is reflected in the significantly higher SRQ. However, the policy dimension remains weak here as well, and quantitative key figures are only available in isolated cases.

The divergence between the two transformation fields stems primarily from differences in the scope and specificity of disclosed measures and targets, rather than from consistent formal anchoring across all PATM dimensions. These differences suggest that positively framed, development-oriented transformation narratives are more readily translated into structured target architectures than restructuring-related topics characterised by heightened reputational sensitivity. These findings constitute the empirical foundation for the subsequent discussion of disclosure and governance logics in the context of workforce transformation.

These results are based on the standardised coding framework and consensus-based validation procedure described in Section 3.4.

5 Discussion

5.1 Disclosure patterns and response logics of workforce transformation

The results indicate a consistent structure of workforce-related reporting following a sequential logic of problem diagnosis, management response and field-specific concretisation. With regard to RQ1, the findings show that the workforce is consistently classified as material within the sample, yet predominantly framed in terms of risks and impacts. Employment security, transformation-related risks and work-related exposures dominate the materiality rationale, whereas value-creation or innovation-oriented perspectives remain marginal. The workforce thus emerges primarily as a risk- and compliance-oriented domain.

This problem framing extends to the PATM level. With regard to RQ2, management responses are predominantly communicated through operational measures and programmes, whereas formally codified policies, coherent target architectures and systematic key performance indicator structures are reported less frequently. Transparency thus derives more from disclosed activities than from structurally embedded and quantitatively substantiated governance architectures. Accordingly, disclosure appears more action-oriented than structure-oriented.

Within this overarching logic, field-specific variations become apparent. Workforce reductions are characterised by a low degree of formalisation and a cautious articulation of targets and key performance indicators, and are predominantly addressed in a situational manner. By contrast, upskilling and reskilling initiatives are more programmatically structured and, in some cases, underpinned by quantified targets. These differences stem less from distinct institutional arrangements than from gradual variations in the scope and specificity of disclosed measures and target architectures.

Beyond these structural differences, qualitative variations also become evident in the linguistic framing. While some companies explicitly refer to workforce reductions and identify concrete, rule-based measures or agreements, others address comparable issues only indirectly within broadly formulated transformation or HR programmes.

The spectrum ranges from clearly specified measures to abstract or positively connoted formulations that linguistically embed or relativise restructuring. These differences pertain less to the existence of measures than to their communicative explicitness. Disclosure thus proves to be differentiated not only structurally but also rhetorically.

With regard to RQ3, the findings indicate only partial integration between IRO diagnosis and PATM operationalisation. Workforce transformation is formally acknowledged as material, yet predominantly presented in an activity-oriented manner and only to a limited extent as a coherently anchored and quantitatively specified governance context.

5.2 Theoretical classification and contribution to the literature

The findings regarding the risk-oriented problem framing of workforce transformation and the predominantly measure-based operationalisation can be situated within central strands of sustainability and disclosure research, which repeatedly highlight a discrepancy between formal disclosure and institutionalised control architectures.

Companies tend to render operational activities visible, whereas formally codified regulations, coherent target architectures and systematically reported key performance indicator structures remain less developed. Transparency thus emerges primarily at the programme level rather than in the form of structurally embedded governance arrangements. Accordingly, workforce transformation appears less as an institutionally integrated control domain than as an operationally addressed field of action. This suggests a limited degree of linkage between materiality diagnosis and the described operational implementation.

This observation aligns with theoretical approaches that differentiate between symbolic and substantive disclosure, according to which reporting does not merely reflect organisational practice but also fulfils legitimising functions. Formal compliance with regulatory requirements does not necessarily coincide with consistent or comparable transparency regarding the underlying management instruments.

The present findings support this perspective: despite ESRS compliance and external auditing, considerable variation persists in the specification of policies, target architectures and quantitative indicators.

Beyond structural differences, qualitative variations are also evident in the narrative framing of disclosure. Restructuring measures, employment adjustments or training initiatives are presented in heterogeneous ways—ranging from explicit references to specific regulations to indirect, abstract or positively connoted formulations.

These findings can be interpreted in light of impression management and narrative disclosure approaches, according to which organisations shape perceptions and legitimacy not only through the scope of information provided but also through its rhetorical construction (Merkl-Davies & Brennan, 2011). Reputation-sensitive issues tend to be relativised or contextualised, whereas future- or performance-oriented initiatives are emphasised more prominently (Higgins & Walker, 2012; Cho et al., 2012).

Disclosure thus appears not merely as a reflection of organisational control, but also as an instrument of selective visibility and narrative framing. Against this background, the present study contributes to the disclosure literature in a multidimensional manner. First, the integration of IRO and PATM perspectives enables a comprehensive examination of problem definition and operationalisation across the entire reporting chain. Second, the dimension-specific differentiation between policies, actions, targets and metrics facilitates a reconstruction of the internal disclosure architecture that extends beyond aggregated transparency indicators. Third, the inclusion of linguistic framing introduces a narrative layer to the structural analysis. Disclosure is therefore conceptualised not only in terms of “whether” or “how much,” but also of “how.”

Overall, the study contributes to a more differentiated understanding of workforce-related sustainability reporting by systematically integrating structural, operational and rhetorical dimensions of disclosure and empirically elucidating their interplay within the context of ESRS S1 implementation.

5.3 Contextual and institutional explanatory approaches

The observed disclosure patterns can be interpreted in light of several contextual and institutional factors. First, workforce reductions in particular are associated with labour law, reputational and socio-political sensitivities that incentivise cautious or indirect reporting practices. Second, training and skills development measures are more readily framed as positive initiatives; however, their effects are inherently more difficult to measure in a standardised manner, which may account for the limited use of quantitative indicators. Third, the structure of the ESRS requirements themselves may generate a framing effect by addressing workforce aspects primarily in terms of impacts and risks.

A risk-centred problem definition tends to privilege compliance-oriented communication over strategic, value-creation-oriented narratives. Taken together, these factors suggest that companies are inclined to present workforce transformation as an operational field of action rather than as a formally institutionalised management object. The resulting disclosure is thus more programme-based than rule-based.

5.4 Regulatory and practical implications

From a regulatory perspective, the findings underscore the continuing scope for interpretation and design in the implementation of the ESRS requirements. Although the standards mandate disclosures on policies, measures, targets and key figures, empirical evidence reveals considerable heterogeneity in their concretisation and degree of formalisation. This heterogeneity hampers comparability across companies and constrains the decision-usefulness of the reports.

For companies, this implies less an expansion of control requirements than an opportunity for clearer and more consistent communication of existing management approaches. Explicit disclosure of policies, target architectures and quantitative indicators, combined with a systematic structuring of workforce-related information along transparent categories such as the PATM logic could enhance the coherence between problem diagnosis, measures and reported outcomes, thereby strengthening transparency and comparability for stakeholders.

5.5 Methodological limitations

The results must be interpreted in light of several methodological limitations. The analysis is based exclusively on published disclosures and therefore does not permit conclusions regarding the actual design, implementation or effectiveness of internal control processes. The study examines the external representation of management approaches rather than their practical application or organisational embedding.

Furthermore, the sample is limited to ten companies and focuses on a specific industry context. Transferability to other industries or company sizes is therefore constrained. Despite the application of systematic coding rules, qualitative content analysis remains inherently interpretative. Multiple coding and consensus procedures enhance intersubjective traceability, yet cannot entirely eliminate subjective elements of evaluation.

The applied 0–3 scale is ordinal in nature; aggregated parameters are interpreted exclusively for descriptive purposes and serve to structure the comparison of disclosure patterns rather than to construct a normative quality index.

Future research may address these limitations through larger, cross-industry samples, longitudinal research designs and the integration of complementary qualitative methods such as interviews or internal document analyses in order to examine more closely the relationship between disclosure architecture and organisational practice. Accordingly, the study does not aim at statistical generalisation in the sense of representative inference, but at analytical generalisation. The findings contribute to the refinement of conceptual relationships between materiality diagnosis, operationalisation and disclosure architecture, which may be transferable to comparable regulatory or industry contexts, while empirical extrapolation beyond the examined cases remains limited.

The supplementary use of AI-supported analytical tools also requires methodological contextualisation. In the present study, AI-based procedures functioned exclusively as validation and plausibility instruments within a human-in-the-loop approach. While algorithmic methods enhance scalability and efficiency, the context-sensitive interpretation of complex disclosures remains a theory-driven

task. Future research should therefore further reflect on the balance between automation, transparency and interpretative validity.

6 Conclusion

This study examines the disclosure of workforce-related transformation processes within the framework of ESRS S1 through the integrated analysis of IRO diagnosis and PATM operationalisation. The findings indicate that workforce transformation is consistently recognised as material, yet predominantly framed in risk-oriented terms and communicated primarily through operational measures. By contrast, a coherently structured, quantitatively specified and systematically integrated governance architecture remains limited in its visibility.

The study thus highlights a central tension in the early implementation of ESRS: a discernible gap persists between the transparency envisaged by regulators and the actual structural integration of workforce-related transformation processes. Disclosure frequently appears activity-oriented and programmatic, rather than as a consistently IRO-linked management architecture comprising explicit policies, target systems and reliable key performance indicators.

Field-specific variations further illustrate this dynamic. While upskilling and reskilling measures are in some cases quantified and operationalised in a target-oriented manner, workforce reductions in particular remain weakly formalised as a sensitive transformation domain and are reported only selectively. This suggests that disclosure architectures are shaped not solely by regulatory requirements, but also by communicative sensitivities, institutional expectations and strategic framing considerations.

Conceptually, the study advances the understanding of disclosure beyond a binary conception of regulatory compliance, framing it instead as a multidimensional configuration encompassing problem definition, governance architecture and narrative design. The integration of IRO and PATM perspectives provides an analytical instrument that enables systematic comparison of structural integration, material specificity and communicative configuration.

For the continued development of ESRS reporting, the findings imply that transparency cannot be achieved through formal standardisation alone, but requires the coherent linkage of materiality diagnosis and operationalised control logic. Whether increasing implementation maturity will result in a deeper structural integration of workforce transformation constitutes a central avenue for future research.

Declaration

We hereby confirm that this section is our original work. It has not been published previously, nor has it been submitted for publication elsewhere. All sources and references have been properly acknowledged and cited in accordance with academic standards.

AI-assisted tools (ChatGPT, OpenAI) were used solely for language refinement and stylistic improvement. All scientific content, analysis, and conclusions are the author's own.

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LECTURERS' PROFESSIONAL READINESS FOR THE USE OF AI: AN ANALYSIS OF STUDENTS' PERCEPTIONS

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The need for AI integration in higher education is growing. It is worth noting that, along with regulations and a systematic approach, the lecturer plays a fundamentally important role, as the student interacts with the lecturer on a daily basis. As part of the research, we analyzed students' perceptions of lecturers' attitudes and professional readiness towards artificial intelligence. The study was conducted at Ivane Javakhishvili Tbilisi State University, in which 791 students participated. The SPSS statistical software package was used to analyze the obtained results. The article presents hypotheses and develops relevant recommendations. According to some students, lecturers' attitude towards artificial intelligence is negative. Furthermore, they believe that lecturers' fear or distrust of AI somewhat limits students. The research identified challenges that can be eliminated by raising the awareness of professors and forming a unified system.

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1 Introduction

Artificial intelligence is one of the most important innovations and challenges of the modern world. It has fundamentally changed the specifics of work in many fields, and the education system is no exception. It is worth noting that the integration of artificial intelligence into higher education institutions is taking place gradually and is fundamentally transforming traditional teaching models. In the face of such large-scale changes, the perception, attitude, and professional and emotional readiness of lecturers towards artificial intelligence are of fundamental importance. This is the basis for the effective and painless integration of artificial intelligence into the educational process, as such large-scale changes require individuals to be ready and open to innovation. The topic is relevant because the issue of integrating artificial intelligence has raised many questions about academic integrity, credibility, and the quality of teaching (Barney 2023). That is why studying lecturers' attitudes and readiness (from the students' perspective) will significantly help us identify key challenges and needs. According to the American Association of Colleges and Universities (AAC&U) and Elon University's Imagining the Digital Future Center survey, 86% of respondents reported that they believe GenAI tools will impact the role and work of those who teach in higher education. Furthermore, 79% believe that the existing teaching model in their department will be affected by GenAI tools. While 43% think that it will have a significant impact. It is worth noting that the use of artificial intelligence tools in the teaching process may lead to a violation of academic integrity. Students may use them dishonestly and violate ethical norms. The results of the survey also confirm this. 78% believe that cheating has increased on their campus. In addition, academic integrity issues and the level of readiness of lecturers are also worth noting (Watson and Rainie 2025). The issue of integrating artificial intelligence into the educational space is a matter of time. For the mentioned reason, the professional and emotional readiness of each lecturer must be very high.

It is worth noting that the desire of lecturers to adapt to innovations alone is not enough. It is necessary to have certain guidelines, a framework, and a strategy to make changes easy to implement (Hwang , et al. 2020), (Kharadze and Pirtskhalaishvili, Integration of artificial intelligence in educational settings and the main challenges. 2026). UNESCO's AI Competency Framework for Teachers is a framework that includes the skills and knowledge that a teacher should possess in the world of artificial intelligence (UNESCO 2024). Such guidelines will help each

lecturer adapt easily. However, in addition to the above, it is important for the country to have a strategy for implementing AI in various sectors, with appropriate guidelines and legislation.

The study was conducted at Ivane Javakhishvili Tbilisi State University, in which 791 students participated. The SPSS statistical software package was used to analyze the obtained results. The questionnaire consisted of 61 multiple-choice questions divided into several sections. The questionnaire was distributed to students electronically, using an internal database and group chats. Furthermore, the chi-square test was utilized to analyse the associations between variables, and Pearson correlation analysis was employed to evaluate the strength and direction of relationships. The quantitative research method was chosen because it is possible to obtain a large amount of data in a short period of time and process it through statistical procedures (Unimrkt 2023).

The study aims to determine the perceptions of students about lecturers' professional readiness towards the use of artificial intelligence. Given that students participated in the study, the findings represent their perceptions.

The study is based on quantitative research, and a fairly large number of respondents participated in it. However, it should be noted that the surveyed respondents represent students from only one university. Despite the large number of respondents, findings from one institution cannot be generalized to the entire higher education system, which is a limitation of the study. In order to see the overall picture and make a comparative analysis, it is crucial to conduct the study in various universities.

2 Research analysis

In the process of analyzing the data obtained during the research, we utilised both simple and complex statistical procedures. Remarkably, only 8.2% of students believe that their lecturers' attitude towards artificial intelligence is positive, 16.8% note that it is mostly positive, 47.3% reported a neutral response, 25.7%, and 2.1% - mostly negative and extremely negative. This perception of students can be viewed from different perspectives. Lecturers may be critical of the integration of artificial intelligence if they believe that the students' contribution to the task is not clearly

visible. For those lecturers who uphold high standards of academic integrity and ethics, plagiarism and artificial intelligence-generated material may be unacceptable, as they are well aware that such an approach hinders students' ability to think critically and poses a threat to their development (Vieriu and Petrea 2026) (Chantiri 2024). However, it might be probable that some lecturers are unable to use artificial intelligence due to a lack of appropriate competencies. They prefer outdated, traditional teaching methods. Accordingly, the use of artificial intelligence by students is unacceptable to them. It is not surprising that the younger generation considers a large part of its lecturers to be a generation far from modern technologies. It is clear that the educational system needs reform, where the boundaries of the use of artificial intelligence will be clearly defined. We would like to assume that the negative attitude of lecturers towards artificial intelligence is caused by their caution towards ethical norms, and not by a lack of competence and knowledge. To address the mentioned challenge, it is crucial to provide both students and lecturers with more information about the benefits of artificial intelligence.

Within the framework of this research, we considered it important to determine whether lecturers encourage students to utilize artificial intelligence. According to the findings, 11.6% of students note that lecturers actively encourage students to use artificial intelligence, while 57.8% have a neutral attitude, and 30.6% report that lecturers are against using AI and forbid it. We can assume that the use of artificial intelligence is not integrated into universities, and only a small group of lecturers implement it on their own initiative. Additionally, some lecturers may not encourage students to use artificial intelligence due to the absence of guidelines and regulations. It is also noteworthy that the university is mainly staffed by personnel above middle age and, accordingly, the integration of artificial intelligence is associated with certain challenges (Kharadze, Pirtskhalaishvili and Dugladze 2022). The effective incorporation of artificial intelligence in the teaching process requires relevant competencies, which are lacking among professors of various age groups. It should also be noted that the use of artificial intelligence varies depending on different specialties. Specifically, it is more commonly employed in the business field and less in the humanities. However, the difference may diminish over time. It is clearly evident that outdated teaching methods dominate in the educational process, and in the modern, rapidly changing world, it is crucial to adapt to innovations to be in line with existing requirements.

It is undeniable that the proper use of artificial intelligence increases students' efficiency, while reducing time losses and increasing the likelihood of personalized learning (Kwak 2025). That is why it is crucial for students to use AI in accordance with ethical standards. To the question, "Do lecturers explain to students how to use artificial intelligence in compliance with ethical standards?" 24.5% of students reported a positive answer. 44.8% of the surveyed respondents have the opposite opinion, while 30.7% do not remember and/or do not have an answer (see Figure 1). We can clearly focus on several concerns: either lecturers lack the required competency, and that is why they choose outdated teaching methods, or they do not want to allocate time, and do not have the motivation. One of the primary responsibilities of the university is to integrate artificial intelligence into the educational process. Since the problem is quite systemic, it is important for the university to ensure that both students and lecturers follow guidelines and regulations so that the artificial intelligence tool can be used as a supporting resource and not for academic fraud. The problem is evident; technological changes are taking place rapidly in the educational system, and lecturers are failing to adapt.

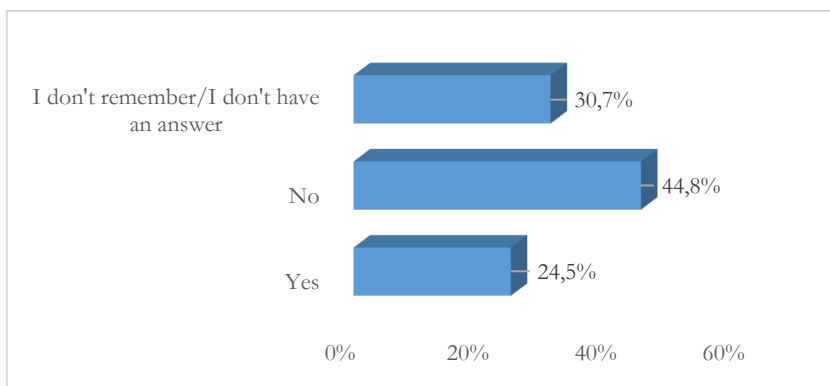


Figure 1: "Do lecturers explain to students how to use artificial intelligence in compliance with ethical standards?"

Source: own.

40.9% of students stated that lecturers use artificial intelligence. While 19.3% stated the opposite. Furthermore, 39.7% of respondents do not have an answer. Such an assessment demonstrates that digital innovations are being introduced less in the educational process, and only certain professors utilize AI tools. Notably, the effect of the generation gap in universities is noticeable, which is manifested both in the

teaching process and in the professors' ratings. The fact that a large part of the respondents do not know at all whether the lecturer uses artificial intelligence indicates another problem, namely, the lack of communication. There is no doubt that modern challenges require the lecturer to update knowledge at a rapid pace (Kharadze, Giorgobiani, et al. 2021).

Whether lecturers' attitude towards artificial intelligence is determined by their age or not, the students' responses were distributed as follows: "Young lecturers are positive" is noted by 56.7%. "The older generation is positive" was noted by 4.7%, while 22.2% believe that age does not affect, and 16.2% do not have an answer. The directly asked question also revealed that the attitude towards modern technologies is different in different age groups, which hinders the teaching process. Professors in our country are not the only ones facing this problem. Numerous studies have revealed that professors of the older generation are skeptical about the application of artificial intelligence and have difficulty adapting to modern technological advancements. However, it should be mentioned that not all of them follow the mentioned trend. Many senior professors are able to successfully adjust to all changes. The opinion of students confirms the same, with 69.4% stating that lecturers should be trained to better utilize artificial intelligence tools, 10.9% disagreeing with the opinion, and 19.7% of respondents did not have an answer to the question.

During the research process, we found it interesting to determine how lecturers control whether a student has used any artificial intelligence tools. 28.2% of students noted that lecturers use various tools to check (Turnitin, SafeAssign), 35% noted that lecturers ask additional questions, and 19.4% gave "other answer". In addition, 17.4% of the surveyed respondents believe that there is no control from the lecturer (see Figure 2). It should also be noted that plagiarism checking for BA students who prepare essays is not carried out in most cases. This issue is more or less regulated at the MA level, not in individual disciplines, but at the stage of preparing a master's thesis. In addition, we believe that control should not serve to prohibit the use of artificial intelligence tools. It is fundamentally important that students know how to use them effectively (Palaganas and Bajwa 2024). It is also worth noting that 35.1% of the surveyed students believe that the control mechanisms established by lecturers are not effective at all.

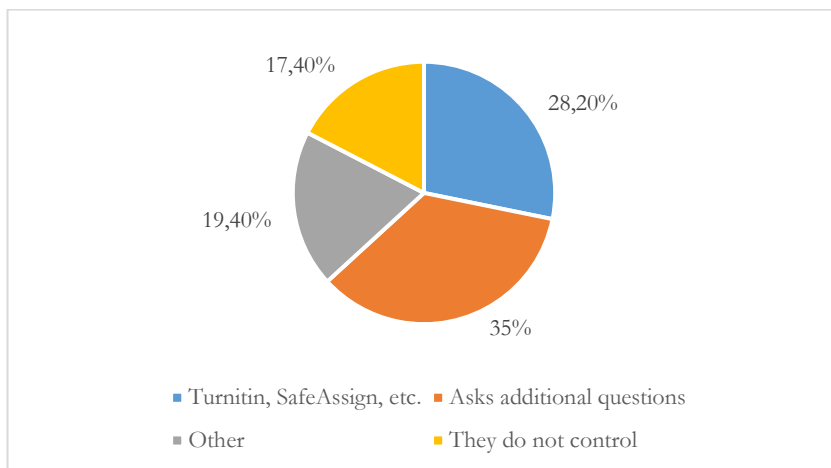


Figure 2: "How do lecturers control that students do not use AI for assignments?"

Source: own.

The following hypotheses were formulated during the research process:

- H1. Lecturers' attitudes towards artificial intelligence influence whether they encourage students to use AI in the learning process;
- H2. According to students, whether or not lecturers explain to students how to use AI ethically influences how fairly they use it;

To test the presented hypotheses, we utilized cross-tabulation, chi-square test, and correlation analysis. The cross-tabulation table used to test the first hypothesis demonstrates that 63.5% of respondents who believe that their lecturer's attitude towards artificial intelligence is very positive also believe that they actively encourage students to use AI in the learning process. However, the picture changes radically in the case of lecturers who have a negative attitude towards artificial intelligence. 68.8% of them warn students or prohibit the use of artificial intelligence. Such a result is not surprising (see Table 1). The negative attitude of lecturers can be associated with many factors: lack of information, fear that students will lose their ability to think independently, lack of guidelines, and a unified system at the university level, etc.

Table 1: Crosstabulation - 31. In your opinion, what is the attitude of most of your lecturers towards AI?/ 32. Do lecturers encourage students to use AI in the learning process?

			32. Do lecturers encourage students to use AI in the learning process?			Total
			Yes, they actively encourage;	They are neutral;	They prohibit the use of AI	
31.In your opinion, what is the attitude of most of your lecturers towards AI?	very positive	Count	40	21	2	63
		% within 31.	63,5%	33,3%	3,2%	100,0%
	Mostly positive	Count	26	93	9	128
		% within 31.	20,3%	72,7%	7,0%	100,0%
	Neutral	Count	16	261	84	361
		% within 31.	4,4%	72,3%	23,3%	100,0%
	Mostly negative	Count	6	62	128	196
		% within 31.	3,1%	31,6%	65,3%	100,0%
	Very negative	Count	1	4	11	16
		% within 31.	6,3%	25,0%	68,8%	100,0%
Total		Count	89	441	234	764
		% within 31.	11,6%	57,7%	30,6%	100,0%

Source: own

The results of the chi-square test showed that there was a statistically significant relationship between the variables ($p < 0.001$) (see Table 2). In addition, correlation analysis was used to determine the strength of the relationship, which shows that there is a positive relationship of medium strength between the presented variables ($r = 0.552$). Accordingly, hypothesis 1, **“Lecturers' attitudes towards artificial intelligence influence whether they encourage students to use AI in the learning process,”** is confirmed.

Table 2: Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	363.061 ^a	8	0,000
Likelihood Ratio	302,255	8	0,000
Linear-by-Linear Association	232,596	1	0,000
N of Valid Cases	764		
a. 2 cells (13.3%) have expected count less than 5. The minimum expected count is 1.86.			

Source: own.

The cross-tabulation analysis table used to test the second hypothesis clearly demonstrates that those students to whom lecturers teach how to use AI tools ethically (35.8%) indicate that most students use AI fairly. In addition, the majority of students who are not informed by lecturers believe that students do not use AI tools fairly. We believe that if students are informed and trained on how to utilise AI without going beyond the ethical framework, they will use it more fairly. For this, it is necessary for the university to establish certain policies and procedures to make it easier for lecturers to provide information. We used the chi-square test to determine the relationship between the variables. The results demonstrated that there is a statistically significant relationship between the variables ($p < 0.001$) (see Table 3). In addition, correlation analysis was used to determine the strength of the relationship, which shows that there is a weak positive relationship between the presented variables ($r = 0.274$). Accordingly, the second hypothesis is confirmed: "According to students, whether or not lecturers explain to students how to use AI ethically influences how fairly they use it".

Table 3: Chi-Square Tests

	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	74.701 ^a	4	0,000
Likelihood Ratio	69,367	4	0,000
Linear-by-Linear Association	57,480	1	0,000
N of Valid Cases	765		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 33.98.			

Source: own

The results of the study clearly show that it is important to have a unified policy at the university. In addition, each lecturer should be trained to provide information to students correctly, so as not to violate academic integrity.

3 Conclusions and recommendations

Several important findings emerged during the research process. Only a small proportion of the surveyed respondents believe that lecturers have a positive attitude towards artificial intelligence. In addition, testing the hypotheses confirmed that the lecturer's attitude towards artificial intelligence affects whether he/she encourages students to use artificial intelligence. It is worth noting that lecturers rarely provide

students with detailed instructions on how to use AI ethically, which increases the risk that students will use it dishonestly. In accordance with the findings, students consider that lecturers' negative attitudes toward AI may limit their use of AI tools. It is also worth emphasising that the presented study relies on students' perceptions and does not directly assess professors' competence. Accordingly, the findings should be interpreted with great caution.

We believe the university should have a unified policy to protect academic integrity. Additionally, it is important to conduct training so that lecturers have the relevant skills. Along with lecturers, training should be conducted for students on utilizing various tools without violating ethical norms. Furthermore, it is crucial to develop an artificial intelligence policy framework at the institutional level. We believe that the topics presented in various disciplines should be reviewed and the syllabus should be edited accordingly, in which issues related to artificial intelligence will be integrated. In the modern world, we cannot avoid existing innovations. It is essential for the university and its personnel to quickly undergo the adaptation process so that the teaching process is more productive.

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SUSTAINABILITY LEADERSHIP DEVELOPMENT AMONG STUDENTS IN HIGHER EDUCATION: EVIDENCE FROM UKRAINE

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Higher education serves as an essential platform for developing sustainability leaders; therefore, the purpose of this study is to identify the potential, gaps, and directions for strengthening sustainability leadership among students. In a survey, the attitudes of management students were investigated regarding components of sustainability leadership potential, including cognitive, learning, value-oriented, behavioural, and leadership identity, as formulated by the authors based on relevant leadership concepts. The study also focused on the peculiarities of students' perceptions of sustainable development priorities in a country at war. The results indicate greater awareness and a greater willingness to learn more about sustainability among master's students, recognition of the high importance of a sustainable approach to management, but also significant concern about the realism of its implementation. A high intentional component positively impacts the sustainability leadership position. The phenomenon of a more active stance on the role of a sustainable leader, coupled with low awareness of the sustainability concept, warrants further research. The research explores challenges in developing sustainability leaders within higher education institutions and suggests corresponding responses.

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1 Introduction

Sustainable development focuses on developing humanity by using resources in a regenerative way while protecting natural systems. Sustainability leadership is based on prioritising actions for sustainable development to ensure implementation of the Sustainable Development Goals (SDGs). Sustainability leadership is implemented at the individual, organisational, national, and global levels. The willingness of top management to include the broadest possible range of external stakeholders (Tal & Gordon, 2016) in the focus of strategic decision-making determines the critical importance of responsible leadership (Maak & Pless, 2006; Marques et al., 2018) in implementing the current agenda for the transition to sustainable business models (Barcellos-Paula, 2021). While institutional progress is notable, the real achievement of SDGs depends on how individuals and organisations manifest these principles in their daily activities and personal lives (Williams, 2021). The greater effectiveness of training in developing leadership skills in students, compared to already practising managers (Muff et al., 2022), identifies higher education institutions as an important platform for accelerating sustainable development. This perspective assumes that, to implement sustainable development, universities must undergo a process of change towards greater sustainability, and, according to change management theory, leadership is essential to this process.

The focus of our research borders on the individual and organisational levels of sustainability leadership, on the one hand, determining the potential for such leadership in students, which, on the other hand, is the reflection of the level of sustainability leadership at the organisational level - the level of a higher educational institution. Thus, the study aims to identify the potential and areas for strengthening sustainability leadership among students in higher education.

The war in Ukraine has significantly transformed the management priorities for sustainable development: in conditions of physical threat, infrastructure destruction, loss of markets and human capital, the focus of companies has shifted from long-term sustainable development strategies to issues of survival, operational continuity and financial stability (KPMG Ukraine, 2025). Sustainability leadership practices - particularly the integration of ESG principles into strategy, the institutionalisation of social responsibility, and environmental innovations - often fade into the background due to limited resources and high uncertainty. At the same time, it is

this reduction in attention to systemic approaches to sustainability that increases the relevance of scientific analysis of the drivers for the potential of sustainability leadership in future managers for the transformation of leadership practices in crisis conditions, because the ability of Ukrainian companies to combine adaptability with value-based management depends on their long-term competitiveness and contribution to post-war recovery.

2 Background

2.1 Sustainable Development and Leadership

The most widely accepted academic definition of sustainable development, established by the Brundtland Report, describes it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 42). The United Nations has established 17 Sustainable Development Goals that address various aspects of life, particularly those that require urgent attention and action (United Nations, 2015a). These 17 interrelated goals constitute a universal call to action to eradicate poverty, protect the environment, and ensure equal opportunities for the world's citizens.

Overall, the Sustainable Development Goals serve as a comprehensive blueprint for achieving a better and more sustainable future for all. However, as noted by Leal et al. (2024), the concept has been viewed from several perspectives, which have changed its meaning and led to numerous definitions (Leal et al., 2024, p. 1). In comparing historical frameworks, sustainable development has evolved from the Millennium Development Goals, which primarily targeted poverty in developing countries, to the 2030 Sustainable Development Agenda (United Nations, 2015b).

The current Sustainable Development Goals framework is broader and more integrated, promoting global action across all countries regardless of income status. Academically, sustainability is understood through the sustainability tripod, which requires a continuous balance among three pillars: environmental quality, economic prosperity, and social justice (Klein et al., 2022, p. 2).

Unlike conventional development methods, which often fell short of ecological constraints, the modern SDG framework accounts for technological, lifestyle, and governance changes to minimise trade-offs among these pillars.

Leadership is a complex phenomenon defined by the ability of individuals to influence, motivate, and enable others to contribute to the effectiveness and success of their organisations (Eustachio et al, 2023, p. 2). Van Seters and Field (1990) explored an evolutionary perspective and created an evolutionary tree of leadership theory. They identified nine evolutionary epochs and outlined the requirements for a tenth epoch of leadership theory, each comprising multiple periods and encompassing a wide range of theories and conceptual approaches (Van Seters & Field, 1990). Therefore, researchers investigating this domain encounter a diversity of definitions, reflecting the breadth of perspectives within the field (Muff et al., 2022; Eustachio et al., 2023; Arokiasamy et al., 2025). In comparing modern leadership paradigms, researchers distinguish among several key styles: transformational leadership, ethical leadership, and responsible leadership.

Transformational leadership is commonly described as a process in which leaders inspire colleagues and followers to reframe their work and view it from a new perspective. It focuses on the how-to of leading internal stakeholders by motivating colleagues to drive a specific change. Transformational leaders prioritise developing their subordinates' full potential, values, higher-order needs, moral principles, and intrinsic motivations. Transformational leadership encourages individuals to collaborate, reframe their perspectives, and place organisational objectives above personal interests (Muff et al., 2022, p. 275). Arokiasamy et al. (2025) identify four core dimensions of transformational leadership: articulating an inspiring vision, fostering intellectual stimulation, demonstrating idealised influence, and showing individualised consideration.

Ethical leadership is characterised by the leader's moral integrity, strong values, and the consistency between these values and their actions. It emphasises cultivating a favourable organisational climate by encouraging ethical behaviour, self-awareness, and moral responsibility. This is important because it contributes to the creation of a constructive psychological atmosphere among employees, increases creativity, and strengthens emotional commitment (Arokiasamy et al, 2025; p. 46).

Responsible leadership extends beyond the organisation, viewing leadership as a purposeful, collaborative, values-based process aimed at positive social change. Alongside previous concepts focusing on the internal stakeholders, the notion of responsible leadership adds a new perspective to leadership thinking. It includes the reasoning that one of a leader's responsibilities is to act as a citizen and public servant, weighing the interests of all parties, adding value to the solution, and prioritising the most affected first, before their own or their organisation's interests. This external, societal orientation calls for a leader to be a custodian of social, moral, and environmental values and resources, summarising that he is a citizen committed to all parties, including those underrepresented, unheard, or unable to speak (e.g., the planet or future generations). The societal focus of responsible leadership connects to a sustainability concept that describes truly sustainable organisations. (Muff et al., 2022, p. 275).

In the context of Higher Education, leadership is identified as the primary engine for large-scale, sustainable reform. It is recognised that universities play a pivotal role in advancing the United Nations Sustainable Development Goals. Higher Education Institutions have an inherent responsibility to generate knowledge and develop the next generation of leaders capable of delivering the SDGs (Findler et al., 2019; Eustachio et al., 2023; Filho et al., 2024; Vesperi et al., 2024). The UN Sustainable Development Solutions Network (SDSN) further outlines this role through four key activities: generating knowledge, cultivating current and future leaders, demonstrating measurable impact, and fostering cross-sectoral collaboration (UN SDSN, 2017).

2.2 Sustainability Leadership

Sustainability leadership is considered an integrating concept of modern approaches to leadership, grounded in responsibility, ethics, and a long-term development perspective, with a focus on active action in a specific context (Visser & Courtice, 2011). A sustainable approach to management typically involves enduring, resilient leadership that focuses on succession planning, maintaining a cycle of positive energy, and building a culture that persists beyond a specific leader's tenure.

Researchers of relevant leadership concepts identify different core components and competency dimensions essential for Sustainability Leadership. Muff et al (2022) connect responsible leadership with a sustainability concept. They structure it around five primary dimensions: systems thinking (understanding interconnectedness), ethics and values (a values-based stance), stakeholder relations (developing long-term relationships), self-awareness (inner knowing), and change and innovation (driving impact for society and the planet).

Based on Michael Fullan's framework, sustainability leadership for organisational improvement comprises five "action-and-mind sets" for effective leaders: a robust sense of moral purpose, an awareness of the dynamics of change, emotional intelligence for nurturing relationships, a dedication to cultivating and sharing new knowledge, and an ability to create coherence (Fullan, 2002).

Sustainability leadership is a promising concept for educating students to develop specific competencies needed to implement sustainable development (Eustachio et al, 2023). The literature also highlights sustainability leadership in higher education institutions. The findings concluded that management staff (e.g., programme coordinators, directors, deans, etc.) are sustainability leaders and explored their traits, behaviours, knowledge, and other qualities they should possess to successfully promote change towards sustainability. Teaching staff can be considered leaders and followers at the same time, as they may be influenced by their superiors (e.g., programme coordinators, directors, etc.) and act as leaders when interacting with students and external stakeholders (e.g., civil society). In addition, students can be seen as sustainability followers in the classroom context, where they may experience different sustainability teaching and learning approaches and practices chosen by teaching staff, with the hope that they will eventually become sustainability leaders (Eustachio et al., 2023, p. 2).

Stek et al. (2025) developed a competency-based course structure that presents an innovative educational framework, preparing students to excel in leadership roles that drive sustainability and innovation. The course structure aims to provide the necessary basic knowledge and competencies: analytical skills; creativity and curiosity; holistic thinking; critical thinking; cross-functional teamwork; digitalisation skills; negotiation; leadership and communication; risk management; strategic thinking; and stakeholder management.

3 Research Context

Ukraine pursues a consistent policy in sustainable development, reflected in its accession to the UNESCO High-Level Steering Committee for SDG 4: Education 2030. This decision gave the state a voice in shaping global educational priorities and strengthened its position in the international arena. Participation in the Committee ensures Ukraine's integration into the definition of strategic directions for education development, monitoring progress on SDG4, and formulating goals after 2030 (Interfax-Ukraine, 2026).

A necessary confirmation of Ukraine's international influence is the initiative to establish the International Science Day for Sustainable Development, which is celebrated annually on November 27. This initiative demonstrates the potential of young researchers and opens opportunities for universities to develop "scientific diplomacy" and foster a leadership identity among students (National Council of Ukraine, 2025).

Integration programs into the EU Green Deal, such as the "Green Deal Ukraine," demonstrate the combination of educational policy, European integration, and climate priorities. The project "Green Transformation in Ukrainian Universities", implemented jointly with NAWA and a consortium of technical universities, provides for green standards, a "green campus" model, specialized courses, and a micro-certification system. The initiative forms an "ecosystem of excellence" that prepares students for infrastructure modernization and strengthens the role of universities as centres of social and environmental innovation (National Agency, 2025).

Despite 42% of Ukrainian company leaders confirming full commitment to previously defined ESG priorities, the pace of their implementation is significantly behind global trends, where companies are moving to the scaling and transparent reporting stage (KPMG Ukraine, 2025). In Ukraine, there is a shift in management focus to anti-crisis competencies – flexibility, speed of decision-making, and risk management – while climate responsibility and inclusion are not considered as top priorities. More than half of Ukrainian leaders do not take ESG projects into account in investment processes, underscoring the need for research on the transformation

of sustainability leadership practices during the war and in post-war recovery (KPMG Ukraine, 2025).

The article by A. Achasova (2024) emphasises that science and education are key pillars of the transition to sustainable development. Higher education institutions should integrate the components of the European Green Deal – emissions trading, renewable energy, and biodiversity restoration – into their curricula. This ensures the development of "green" competencies in future specialists, necessary for the restoration of the industrial and energy sectors and for Ukraine's inclusion in the European ecological system. Artyukhov (2021) examines the Ukrainian university model through the prism of Sustainable Development Goals 4 (Quality Education) and 7 (Affordable and Clean Energy), emphasising the link between technology transfer and the popularity of "green" educational programs. The study emphasises that since the adoption of the 2030 Agenda, Ukrainian curricula have increasingly focused on energy efficiency and environmental sustainability.

Ukrainian universities are actively implementing projects that promote the Sustainable Development Goals. Among the Erasmus+ initiatives (2024-2025) are those aimed at the circular economy and digital transformation. An example is the Jean Monnet EUNanoGreen module, which integrates the European Green Deal's "zero pollution" provisions into the curriculum. The project combines nanotechnology with environmental policy and builds interdisciplinary competencies, contributing to the development of sustainable leadership and responsibility among students (National Erasmus+, 2025). The UCU Leadership Centre report (2022) emphasises that sustainable leadership development is not only an environmental or economic issue but also a matter of psychological and social resilience. Ukraine is described as a "social laboratory" for powerful transformations, suggesting that leadership development among students and faculty must move beyond steady-state theories to a virtue-based leadership model that can withstand "hostile contexts" (UCU Centre, 2022).

The physical environment of universities is becoming a platform for sustainability leadership practices through participatory planning. Research by Vietrova et al. (2025) shows that involving students in the design of learning spaces in Poland and Ukraine strengthens social capital and responsibility. The campus is transformed into a "living laboratory" where students propose ecological and inclusive solutions,

forming social awareness and civic responsibility. This demonstrates that sustainability leadership is a practical behaviour grounded in interaction with the community and the environment.

Sustainable leaders in higher education institutions combine visionary leadership with student empowerment. Lytovchenko et al. (2021) show that integrating sustainability into university curricula is possible through specialized courses and the use of digital interactive platforms. This demonstrates that sustainability awareness can be developed across all disciplines, integrating professional learning with the development of leadership competencies.

The integration of leadership, innovation, and sustainable development in the Ukrainian context is further developed by conference discussions. Combining academic theory with practical knowledge, the events demonstrated how science and education stimulate progress in leadership and management, shaping a more sustainable and promising ecosystem. For Ukrainian students, this means developing in an interdisciplinary ecosystem that combines innovative business processes with conflict management skills in war and post-war environments (CEEMAN, 2025). Thus, the Ukrainian context adds a unique dimension: leadership in sustainable development is linked to post-war recovery, resilience, and integration into the EU.

4 Methodology

The study employed a cross-sectoral survey design to examine students' perceptions of sustainability leadership. A voluntary, anonymous survey was conducted among management and marketing students at one of the leading economic universities in Ukraine, which enrolls students from all regions of the country. Data were collected via a structured questionnaire completed by 82 students. The questionnaire was distributed to management students, with the suggestion that they pass it along to other students. The result was that 16% of marketing students were included in the sample. Given the related nature of the two fields of study and the inclusion of elective courses on sustainable development in both specialisations' curricula, the sample can be considered homogeneous. Therefore, the analysis was conducted on the complete set of responses without differentiating results by field of study.

Given the lack of a specialised sustainability leadership course in the curriculum and the random sampling method, it was considered unreasonable to conduct a detailed exploration of possible traits, skills, competencies, value orientations, etc.

Focusing on the various components of concepts related to sustainability leadership (sustainable, ethical, responsible, transformational leadership) and recognising the limitations of research on students outside the contextual conditions of practice, as only the potential for its formation at educational institution can be examined, the study focused on the following selected components by the authors:

1. The cognitive component, reflecting students' awareness and knowledge of the sustainability concept.
2. The learning component, capturing their willingness to deepen and expand sustainability-related knowledge.
3. The value-oriented component, indicating the perceived importance of sustainable development principles.
4. The behavioural (intentional) component, representing the intention to implement sustainable practices in future professional activities.
5. The leadership identity component, reflecting the aspiration to assume the role of a sustainability leader.

The analysis focused on descriptive statistics and the examination of associations between selected components. The judgment regarding the level of sustainability leadership components was based on the proportion of the sample that agreed with the corresponding statements in the questionnaire. The instrument consisted of closed-ended questions capturing respondents' awareness of the sustainability concept and their attitudes towards sustainability-related practices. It also included an open-ended question for students to reflect on possible educational improvements to enhance their sustainability leadership. To ensure objectivity in the responses regarding awareness of the concept of sustainability, the questionnaire did not define the category. At the same time, the question regarding ambitions to be a sustainability leader was accompanied by the following definition: a sustainability leader is someone who makes responsible, ethical decisions, considering the long-term impact on people, the environment, society, and the planet. It also explored how students in a country experiencing war understand and prioritise the sustainable development of organisations.

5 Findings and discussion

The study involved undergraduate and graduate students studying management and marketing at one of the leading state universities in Ukraine, specialising in the training of economic specialists. 65.4% of female and 33.3% of male students participated in the survey. 37% of the study participants are enrolled in a master's program. As noted in the methodology section, due to the disproportionate distribution of students across both specialities, the close specialisation, and the possibility of studying sustainable development issues through enrollment in relevant elective disciplines in both specialities, the conclusions were drawn for the entire sample.

Further component- and cross-component interpretation of the responses aims to obtain an in-depth understanding of students' potential for sustainability leadership and to identify gaps and areas for strengthening sustainability leadership in higher education.

5.1 The cognitive component (awareness)

The formation of a sustainable leader with a global vision of sustainable development challenges and an understanding, at the organisational level, of ways to mitigate or address them is based on mastering the principles of sustainable management and appealing to systems thinking.

Analysis of respondents' awareness of sustainable management and leadership issues showed that only 51.3% had studied these issues as part of the curriculum, and 10.3% had not heard of them before. On the one hand, these proportions may indicate a low interest in studying sustainable development issues, given the lack of a related discipline among the mandatory components of the curriculum and, accordingly, the need to enrol in an elective discipline. This conclusion may be more relevant for master's students, since the survey was conducted at the end of the academic year, when studies had already ended. For undergraduate students, not having relevant courses may mean they can elect them later.

Only 38.5% of students reported a complete understanding of the concept of sustainable management, indicating gaps in learning effectiveness, as this proportion is lower than the proportion of students who studied related disciplines (51.3%).

The results show, as noted above, that fewer than 40% of the surveyed applicants fully understand the principles of sustainable management. At the same time, almost half indicated that they studied these issues within the curriculum. Moreover, among the latter, 57% confirmed that they fully understand the sustainable approach to doing business. The remaining 43% agreed with the statement “partially understand”. Higher efficiency in mastering the concept is demonstrated by master's students, among whom 70% fully agree with the understanding of the essence of sustainable management, compared with only 42% at the bachelor's level.

5.2 The learning component (willingness to deepen and expand sustainability-related knowledge)

Almost 70% of respondents volunteered to study sustainable management issues in more depth, and 25.6% expressed interest in such knowledge only if it was for their own interest (benefit). In addition, 80% of master's students and 63% of bachelor's degree applicants reported interest in further studying these issues.

The impact of practical mastery of the principles of sustainable development and management on the formation of sustainability leadership is confirmed by the fact that 90% of students who indicated a complete understanding of the concept of sustainability also affirmed its importance and expressed interest in further in-depth study of these issues. Among students who are only partially aware of sustainable management approaches, the percentage interested in further study of this area is already only 50%. At the same time, among students unfamiliar with this concept, almost 67% want to learn more. That is, there is a general interest among students in sustainable development issues, which increases significantly with greater awareness. From the above, we can assume that academic disciplines should not provide segmented knowledge but rather create a clear, holistic picture of the issues in the sustainable development of organisations. At the same time, individual topics or discussion questions in each discipline related to these issues are a promising direction for strengthening sustainable education in higher education institutions. They will also provide a source of in-depth understanding of specific areas of

influence on sustainable development. Generalisation and implementation of a systematic approach to mastering the concept of sustainable management requires a separate specialised discipline. In order to form the appropriate skills, training on management competencies should include special blocks on sustainable management (leadership).

5.3 The value-oriented component (the perceived importance of sustainable development principles)

The answers regarding the students' perception of the importance of sustainable management are considered indicative. 31% of respondents agreed that this approach to management is critically important. More than half of the surveyed students (55%) recognized the importance. However, they questioned the feasibility of implementing sustainable management in practice, which may be due to both low business activity in implementing sustainable practices and weak promotion and dissemination of information about successful sustainable development projects. The flagships of sustainable development in Ukraine are international corporations with branches in Ukraine, as well as domestic businesses with active business operations abroad. Students form their own perceptions of standard business practices outside the university to a greater extent, either through their own experience, mainly working in small service-sector enterprises, or through their parents' communication, which is often a limited source of information for various reasons. Under these circumstances, university education is considered an important platform for forming a sustainable worldview, disseminating knowledge and successful business practices to help companies transition to sustainable business models, and training future managers to assume active leadership roles in the sustainable development of organisations and in ethical decision-making.

5.4 The behavioural (intentional) component (the intention to implement sustainable practices in future professional activities)

A positive result indicates that respondents have active plans to apply sustainable practices in their professional activities after graduation. Only 6% answered that they were not sure, 45% and 49% chose the answer options “yes, I want” and “rather yes”, respectively. At the same time, from the point of view of future leadership potential, it is striking that every second applicant in the electorate prefers to follow

sustainability standards in their future career but does not state this with confidence. This indicates a need to strengthen students' beliefs in the value of using value-oriented criteria in workplace decision-making. This thesis is also supported by an analysis that found that among applicants who consider further study of sustainable management issues interesting and relevant, 54% are confident in the guidelines for implementing them in practice. Among students who were ready to study sustainable management in depth only if there was personal interest (personal benefit), this percentage of practice-oriented applicants is almost half as low (30%).

The belief influences the activity of the position regarding the standards of future professional activity in the importance and realism of such standards in practice. Thus, 3/4 of students who are undoubtedly convinced of the importance of a sustainable approach to management in the modern world confirmed their readiness to implement sustainable practices in the future. Among those who had doubts about the realistic chances of consistently implementing sustainable practices, such readiness was half as low.

The analysis confirms the positive impact of studying sustainable development courses on the desire to apply sustainable practices in future activities. In particular, among those who have not heard of sustainable practices, only one in four demonstrates a willingness to implement them in their work; among those who know about the principles of sustainable development but have not studied relevant subjects, only one in three; among those who have studied, one in two.

5.5 The leadership identity component (the aspiration to assume the role of a sustainability leader).

The phenomenon of a more active stance on the role of a sustainability leader, compared to the willingness to implement sustainable practices in the future, warrants further analysis: 60% of respondents reported such a desire, while only 45% reported an unquestionable intention to do so in the workplace (see 5.4). Also, an unexpected result shows that the opposite levels of awareness of the sustainability concept are associated with a high desire to be a sustainability leader (Table 1). On the one hand, a higher percentage of respondents who are actively oriented towards sustainability leadership are those who have studied sustainable development issues, compared to those who have heard about these issues but have not studied them

purposefully, which is expected and logical. On the other hand, the highest desire to be sustainable leaders (75% in this group) is observed among those who are not familiar with the concept of sustainability, which may indicate both an idealistic orientation and a lack of awareness of realities. This confirms the importance of researching leadership both in relation to underlying core values and knowledge, and as a separate phenomenon that drives needed changes.

Table 1: Cross-tabulation between Awareness of the Sustainability Concept and Sustainability Leadership Identity (%)

Awareness of Sustainability Management / Leadership	Sustainability Leadership Identity		
	Possibly, if relevant to my field	Yes, I aspire to it	Grand Total
No, not previously aware	25,00%	75,00%	100,00%
Yes, aware but not studied in depth	46,67%	53,33%	100,00%
Yes, studied within an academic program	37,50%	62,50%	100,00%
Grand Total	39,74%	60,26%	100,00%

Source: own

A positive association is demonstrated by the desire to learn more about sustainability management and the guidelines for being a sustainable leader. Thus, if among students with low motivation for in-depth study of the concept of sustainable development, only 25% declared a desire to be a sustainability leader, then among those ready for further study on the condition of their own interest, 55%, and among those definitely interested, 65%.

An active behaviourally oriented position (with a high intentional component) is important for developing sustainability leaders (Table 2). The results indicate a positive association between the intention to implement sustainable practices in future and the intention to engage in sustainability leadership. Respondents with a firm intention to implement sustainable practices demonstrate substantially higher aspirations toward sustainability leadership (77.14%) than those who are uncertain (20%).

Table 2: Cross-tabulation between Intention to Implement Sustainable Practices and Sustainability Leadership Identity (%)

Intention to Implement Sustainable Practices	Sustainability Leadership Identity		
	Possibly, if relevant to my field	Yes, I aspire to it	Grand Total
Unsure	80,00%	20,00%	100,00%
Rather yes	50,00%	50,00%	100,00%
Yes	22,86%	77,14%	100,00%
Grand Total	39,74%	60,26%	100,00%

Source: own

A less obvious association is observed between the perception of the importance of sustainable management problems and the willingness to solve them, that is, to be a sustainability leader. Approximately half of the respondents who do not have a clear opinion or doubt the practical feasibility of implementing sustainable practices want to become sustainable leaders. 60% of those who want to be leaders are among those who are categorically convinced of the critical importance of applying a sustainable approach to management in today's realities.

5.6 Gender-based analysis and the impact of war

A future discussion is needed to examine the results by gender in the students' answers. In particular, 80% of women are open and interested in further studying sustainable development issues, while this share among men was only 46%. In addition, 12% of men generally stated they were unwilling to learn about these issues further (among women, this share is 2%). At the same time, approximately the same share of women and men surveyed (38% each) assured of a complete understanding of the concept of sustainable development, approximately the same share (47% among women and 43% among men) chose the answer about the desire to implement sustainable practices in their future careers. 65% of women and 50% of men see themselves as future sustainable leaders. Answers to similar questions in research conducted before the war showed that women were more motivated to study sustainable development, while men were more active in their plans to implement sustainable business practices after completing their studies. One possible reason for the greater apathy among male students towards planning sustainable activities is the uncertainty about the future caused by the war.

No notable differences were found among students' opinions regarding the impact of war on the relevance of sustainable development. More than half of the respondents noted the following impacts of war: "Increased the importance of social responsibility and long-term thinking" (61%) and "Increased focus on short-term solutions and crisis management" (67%). 42% of the sample surveyed believe that the war "Increased interest in environmental and ethical standards."

6 Conclusion, Limitations, and Future Research

Ukrainian higher education institutions actively contribute to peacebuilding and sustainable development, positioning students and teachers as leaders in resilience and social cohesion. The analysis shows the necessity and importance of teaching students about sustainable development issues, which are positively correlated with their orientations to implement such practices in their professional activities. A high intentional component, in turn, strengthens the leadership identity. In addition, a more active leadership identity was demonstrated not so much by students with a high cognitive component as by those with a high learning component. Nevertheless, the study's results showed a significant gap in learning effectiveness. Although the respondents who studied relevant topics reported a high percentage, they still showed insufficient understanding of sustainable development issues. We also observe a notably higher level of mastery of this knowledge at the master's level, which may indicate both a more responsible, value-oriented position and deeper learning in master's programs.

Cross-component analysis deserves special attention. In particular, with a high share of active orientation towards in-depth learning on sustainable development issues, a quarter of respondents are ready to do so if there are personal benefits.

Among the limitations, the small sample of students at one university makes it difficult to generalise about the potential for sustainability leadership among students in Ukraine and in higher education more broadly.

A separate influence on priorities and, accordingly, on the choice of answer options to the questionnaire questions may be exerted by contextual factors, primarily living in Ukraine and studying almost exclusively in conditions of war.

A minor proportion of responses (12%) demonstrated internal inconsistency regarding prior awareness of sustainable development. These cases were retained in the dataset, as such inconsistencies may reflect varying interpretations of the concept rather than systematic response bias.

Further research should deepen understanding of the sustainability leadership concept, its components and external drivers, and how sustainability leaders develop in higher educational institutions. A promising direction of research is the features of the formation of sustainable leaders, depending on the content of the disciplines students study.

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DIFFERENCES IN FINANCIAL PERFORMANCE OF FIRMS WITH ESTABLISHED CONTROLLING DEPENDING ON THE USE OF AI

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This paper examines the relationship between the use of artificial intelligence (AI) and the economic performance of firms with an established controlling system. The aim of the study is to assess empirically whether accounting and financial indicators differ significantly between firms that use artificial intelligence and those that do not. The research sample consists of firms with established controlling, which are divided into two groups based on their use of artificial intelligence tools. The analysis draws on accounting data and selected indicators capturing cost structure, liquidity-related asset structure and short-term financial position, as well as operating performance and cash conversion efficiency. Given the nature of the data, the nonparametric Mann-Whitney U test is employed to test for differences between the two groups. The results contribute to the ongoing discussion on the role of artificial intelligence in corporate management and controlling by providing empirical evidence on whether AI use is associated with firms' economic outcomes.

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1 Introduction

Digital transformation is reshaping how firms create value, organize work, and make decisions. The literature commonly views it as a gradual process in which digital technologies create disruptions, trigger strategic responses, and lead to changes in value creation and organizational structures (Vial, 2019; Verhoef et al., 2021). Recent reviews also stress that performance outcomes depend on the interaction between technology and organizational change - digital tools rarely improve results on their own, but rather through how they are embedded in routines, capabilities, and control systems (Plekhanov et al., 2023; Volberda et al., 2021).

Within this broader shift, artificial intelligence (AI) is particularly important because it supports both automation and more advanced, data-driven decision support. This is often described as an “automation–augmentation” tension, where AI can replace some tasks while strengthening human judgment in others (Raisch & Krakowski, 2021). In accounting and controlling, this raises a practical and research-relevant question: whether AI use is linked to measurable differences in firm outcomes, especially in organizations that already rely on planning, performance measurement, and variance-based steering.

Research on management accounting and AI is increasingly moving from conceptual discussions to studies that connect AI-related practices with organizational consequences, but empirical evidence remains uneven across settings and outcomes (Abbas, 2025; Stratopoulos & Wang, 2025). In addition, the expected benefits of AI in finance and controlling are likely to depend on enabling conditions such as data quality and availability, governance arrangements, employee skills, and alignment with finance objectives (Bedford et al., 2025; Steens et al., 2024). These considerations motivate an empirical comparison of firms with similar management control conditions that differ in their use of AI elements.

The objective of this paper is to examine empirically whether firms with an established controlling function differ in accounting-based indicators depending on whether they report using AI-related elements. The analysis focuses on three domains observable from financial statements: (i) cost structure, (ii) liquidity-related asset structure and short-term financial position, and (iii) operating performance and cash conversion efficiency. Differences between AI-using and non-using firms are

assessed using the Mann-Whitney U test. To achieve this objective, the study addresses the following research questions focusing on differences within the controlling-implemented subsample:

RQ1: Do AI-using and non-using controlling firms differ in cost structure?

RQ2: Do AI-using and non-using controlling firms differ in liquidity-related asset structure and short-term financial position?

RQ3: Do AI-using and non-using controlling firms differ in operating performance and cash conversion efficiency?

2 Literature review

2.1 The Influence of Capabilities and Management Control on Digital Transformation Outcomes and AI Adoption

Recent digital transformation research consistently shows that performance outcomes depend less on adoption itself and more on how digital technologies interact with organizational arrangements. Digital transformation is commonly described as a process in which technologies create disruptions that trigger strategic responses, while outcomes are shaped by organizational barriers and structural change (Vial, 2019). It also requires coordinated adjustments in strategy, structure, processes, and customer-facing activities, which makes internal governance and decision infrastructures critical boundary conditions (Verhoef et al., 2021). Review studies further emphasize that the field increasingly focuses on how firms overcome cognitive barriers, redesign routines, and develop new organizational forms, reinforcing the role of managerial systems and controls in converting digital initiatives into performance improvements (Plekhanov et al., 2023; Volberda et al., 2021).

From a controlling perspective, these arguments are particularly relevant because controlling can be understood as a formal infrastructure for steering organizations through planning, performance measurement, and variance-based feedback. In this sense, management control systems (MCS) are not merely supportive tools but complementary mechanisms that influence how digital technologies are selected, implemented, and used. Empirical evidence from SMEs suggests that digitalization is associated with the maturity of management control practices and that the realized

benefits depend on organizational conditions that shape this relationship (Broccardo et al., 2024). Conceptual work on management control combinations likewise calls for closer attention to the mechanisms through which sets of controls emerge and affect outcomes - an issue that becomes more salient as digital technologies increase data granularity, timeliness, and the pace of decision cycles (Bedford, 2020).

AI differs from earlier waves of digitalization because it can automate tasks while also augmenting managerial judgment through predictive and generative capabilities. The automation–augmentation paradox highlights that AI may improve efficiency in some areas while creating new coordination and governance challenges, including overreliance and accountability concerns (Raisch & Krakowski, 2021). Studies on AI for decision-making emphasize that value depends on integrating AI outputs into decision processes, maintaining data quality, and aligning AI use with managerial information needs (Duan et al., 2019). A capability-based view has therefore become central to explaining why AI outcomes vary across firms: AI capability is typically defined as a configuration of resources and routines that enables effective deployment and is empirically linked to performance outcomes (Mikalef & Gupta, 2021). Related evidence in information systems reports a similar association, while stressing that effects depend on complementary organizational conditions and the broader digital context (Fosso Wamba et al., 2024). Financial economics research also suggests that AI investment is associated with higher firm growth and valuation, with growth largely driven by product innovation, which supports the idea that AI can reshape competitive dynamics through capability development (Babina et al., 2024).

2.2 Digitalization in Finance and Controlling and the Accounting Visibility of AI Effects

Digital transformation increasingly unfolds within the finance function, where automation and analytics reshape both routine work and the advisory role of controllers. However, the uptake of these tools is uneven and tends to reflect a firm's broader digital strategy as well as the orientation of the finance function toward efficiency gains versus business partnering (Bedford et al., 2025). Management accounting research therefore cautions against treating digitalization as a simple, linear change with direct performance effects. Digital data environments alter practices because data become more granular, abundant, and machine-processable

(Bhimani, 2020), and they can also influence organizational boundaries, power relations, and the ways in which accounting knowledge is produced (Knudsen, 2020). Recent evidence further suggests that the ability to benefit from analytics and AI depends on competencies, as controllers increasingly require digital skills and structured competence development (Steens et al., 2024). Field-based insights from forecasting and analytics projects similarly indicate that benefits often emerge through staged implementation rather than immediate large-scale transformation (Schnegg & Möller, 2022). Taken together, these studies imply that AI value in controlling is typically conditional on organizational embedding, governance, and skills, rather than on adoption alone.

Against this backdrop, accounting-based indicators offer a practical lens for examining whether AI-enabled controlling is associated with observable differences in firm outcomes. Recent syntheses map the intersection of AI and management accounting and call for empirical work that links AI-enabled practices to organizational consequences (Abbas, 2025; Stratopoulos & Wang, 2025). Research also highlights that firms often scale simpler AI applications more widely than complex tools and face persistent challenges related to explainability, bias, privacy, robustness, and overreliance (Kokina et al., 2025). Evidence on automation likewise shows that implementation outcomes depend on process clarity, governance, and careful human–machine design (Perdana et al., 2023), while broader assessments point to ongoing pressures on accounting professions to adopt new methods and competencies (Tiberius & Hirth, 2019). These insights converge on a key implication: observable performance differences between AI-using and non-using firms are most likely when AI is integrated into routines supported by appropriate capabilities and governance.

Overall, the literature suggests that AI embedded in finance and controlling routines has the potential to enhance decision quality, forecasting, reporting, and operational efficiency. However, these benefits are unlikely to arise from technology adoption alone. They depend on data quality, digital competencies, governance arrangements, and the extent to which AI outputs are integrated into managerial decision-making processes. Accounting-based indicators therefore provide a useful, although necessarily limited, lens for examining whether AI use is associated with observable differences in firm outcomes. In response to recent calls for empirical research linking AI-related practices to organizational consequences, this study compares

firms with established controlling that differ in reported AI use and examines whether these differences are reflected in selected financial-statement indicators.

3 Methodology

This research combines questionnaire-based primary data with secondary accounting and financial statement data. The primary data come from a questionnaire survey capturing firm practices and managerial approaches, including whether the firm has implemented controlling and whether it uses AI-related elements. In addition, secondary accounting and financial statement data were used. These financial data were obtained from the Albertina Gold Edition database and matched to the survey responses at the firm level.

In total, 201 valid questionnaire responses were collected. Among the participating firms, 74 reported that controlling is implemented, while 127 reported that controlling is not implemented or that they only use basic cost accounting tools. The conference analysis focuses on the subsample of firms with controlling implemented. This subsample initially included 74 firms, but after data cleaning and the matching of survey responses with financial statement records, the final analytical sample consisted of 64 firms. Within this final sample, firms were classified according to reported AI use: 41 firms were categorized as AI-using firms, and 23 firms as non-AI firms. AI use is measured in this study as a binary variable. Firms were classified as AI-using firms if they reported the use of AI-related elements, and as non-AI firms if they did not report such use. This operationalization is suitable for an initial exploratory comparison because it enables the analysis to identify whether the presence of reported AI use is associated with differences in accounting-based indicators within firms that already have controlling implemented. However, the measure does not capture the intensity, maturity, functional scope, or specific type of AI application. Firms classified as AI-using firms may therefore differ in the extent to which AI is embedded in controlling processes, financial planning, reporting, forecasting, or managerial decision support. For this reason, the results should be interpreted as evidence of differences associated with reported AI use rather than as evidence of the effects of advanced or fully integrated AI-based controlling systems. Future research should develop more granular measures of AI adoption, for example by distinguishing between basic automation, predictive analytics, generative AI applications, decision-support systems, and strategically

integrated AI-based controlling solutions. All statistical tests and comparisons reported in this paper are therefore based on this cleaned and matched subsample ($N = 64$).

The study uses six accounting-based indicators, grouped into three domains. The first domain captures cost structure through the administrative cost ratio and the personnel cost ratio, reflecting both potential short-term implementation costs and process-related efficiency effects. The second domain focuses on liquidity-related balance-sheet characteristics, measured by financial assets as a share of total assets and the cash ratio, which together describe the firm's liquid asset position and short-term financial buffer. The third domain captures operating performance and cash conversion, using operating profit margin and days sales outstanding (DSO), to assess whether differences in cost structure and liquidity management are reflected in operating outcomes and receivables collection efficiency. The six indicators are organized as follows:

Group 1: Cost structure and cost discipline

1. Administrative cost ratio (Administrative and other expenses / Operating revenues)
2. Personnel cost ratio (Personnel expenses / Operating revenues)

Group 2: Liquidity-related asset structure and short-term financial position

3. Financial assets as % of total assets
4. Cash ratio (immediate liquidity)

Group 3: Operating performance and cash conversion

5. Operating profit margin (Operating profit / Operating revenues)
6. Days sales outstanding (DSO) (Days receivables turnover)

Statistical methods

Testing for normality of data distribution

Prior to the empirical analysis, the distributional properties of the analysed financial indicators were examined to inform the choice of appropriate statistical methods. Testing for normality represents a standard procedure in empirical research based on accounting data, particularly in comparative studies. The variables were assessed using the Shapiro-Wilk test, which is commonly applied in empirical accounting and financial research (Shapiro & Wilk, 1965; Field, 2018).

The results indicate that a considerable proportion of the analysed indicators deviates from a normal distribution. Such distributional patterns are typical for accounting-based financial data, which are frequently affected by skewness and extreme values. Given the violation of the normality assumption, the application of parametric statistical methods was deemed inappropriate, and the subsequent analysis therefore relies on non-parametric techniques.

Testing of relationships by Mann-Whitney U test

The Mann-Whitney U test was used to examine differences in financial characteristics between AI-using and non-AI firms with implemented controlling. This non-parametric test is suitable for comparing two independent samples when the assumption of normality is violated (Nachar, 2008; Devore, 2015).

The Mann-Whitney U test evaluates whether the distributions of a given financial indicator differ between the two groups. The test was applied separately to each financial indicator to assess whether statistically significant differences exist between firms. Although the sample sizes differ between the groups, the Mann-Whitney U test remains appropriate, as it is robust to unequal group sizes and does not rely on distributional assumptions.

All tests were evaluated at a significance level of $\alpha = 0.05$. This approach is consistent with the formulated research questions.

4 Results

4.1 Testing for Normality of Data Distribution

Prior to hypothesis testing, the distributional properties of the analysed variables were examined to determine the suitability of subsequent statistical procedures. The normality of the data and the distribution of the sample were assessed using the Shapiro-Wilk test, which is widely recommended for evaluating normality in empirical research (Shapiro & Wilk, 1965; Field, 2018).

The results of the Shapiro-Wilk test indicated that the assumption of normal distribution could not be confirmed for a substantial part of the analysed financial indicators. This finding is consistent with the characteristics of accounting and financial data. Consequently, the subsequent analysis relied on non-parametric statistical methods that do not require normality of the data and are robust to deviations from standard distributional assumptions.

4.2 Mann-Whitney U test

Differences between AI-using and non-using firms were assessed using the Mann-Whitney U test, which is suitable for financial statement indicators that are typically non-normally distributed and may include outliers. The test evaluates whether the distributions of an indicator differ between two independent groups by comparing rank positions rather than raw values. In Table 1, “Sum (NO)” and “Sum (YES)” represent the sums of ranks for the non-AI and AI groups, respectively. Higher mean ranks indicate higher typical values of the indicator in the respective group. Because not all firms had complete information for every indicator, the number of observations differs slightly across indicators.

Table 1: Mann-Whitney U Test Results for Differences in Accounting-Based Indicators Between AI-Using and Non-AI Firms

Financial Indicator	Sum (NO)	Sum (YES)	U	Z	p-value
Administrative cost ratio	415	1016	205	-2.284	0.022
Personnel cost ratio	544	887	326	0.064	0.948
Financial assets as % of assets	650	781	220	2.009	0.044
Cash ratio	579	799	271	0.912	0.361
Operating profit margin	507	924	297	-0.596	0.550
DSO	573.5	857.5	296.5	0.605	0.544

Source: own processing

Group 1: Cost structure and cost discipline

The first group includes the administrative cost ratio and the personnel cost ratio, both expressed relative to operating revenues. The administrative cost ratio exhibits a statistically significant difference between AI-using firms and non-AI firms ($U = 205$; $Z = -2.284$; $p = 0.022$). The rank distribution indicates higher values among AI-using firms, as reflected by a markedly larger rank sum in the AI group ($\text{Sum(YES)} = 1016$) compared to the non-AI group ($\text{Sum(NO)} = 415$). In substantive terms, this suggests that firms reporting AI use tend to show a higher administrative cost burden relative to operating revenues. The differences are shown in Figure 1.

By contrast, the personnel cost ratio does not differ between the groups ($U = 326$; $Z = 0.064$; $p = 0.948$). Rank sums are nearly identical in relative terms, indicating that labor cost intensity does not distinguish AI-using firms from non-using firms in this dataset. Taken together, these results suggest that group differences within the cost structure domain are concentrated in administrative and related overhead-type expenditures rather than in personnel cost intensity.

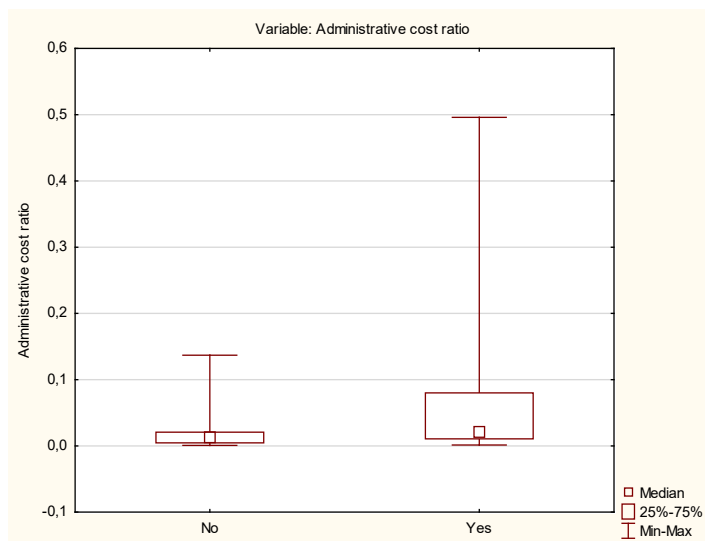


Figure 1: Mann-Whitney U Test - Administrative Cost Ratio

Source: own processing

Group 2: Liquidity-related asset structure and short-term financial position

The second group includes financial assets as a percentage of total assets and the cash ratio, which together capture liquidity-related asset structure and the short-term financial position. Financial assets as a percentage of assets shows a statistically significant difference between the groups ($U = 220$; $Z = 2.009$; $p = 0.044$). Here, the rank pattern indicates that non-AI firms tend to have higher values of this indicator ($\text{Sum(No)} = 650$) than AI-using firms ($\text{Sum(Yes)} = 781$), implying a higher relative allocation to financial assets among non-AI firms. The differences are shown in Figure 2.

The cash ratio, however, does not show a statistically significant difference ($U = 271$; $Z = 0.912$; $p = 0.361$). Although the ranks suggest a tendency toward higher immediate liquidity among non-AI firms, the observed difference is not sufficiently consistent to be statistically supported in this sample. Overall, the results in this group indicate that the most robust distinction concerns the composition of assets rather than cash holdings alone.

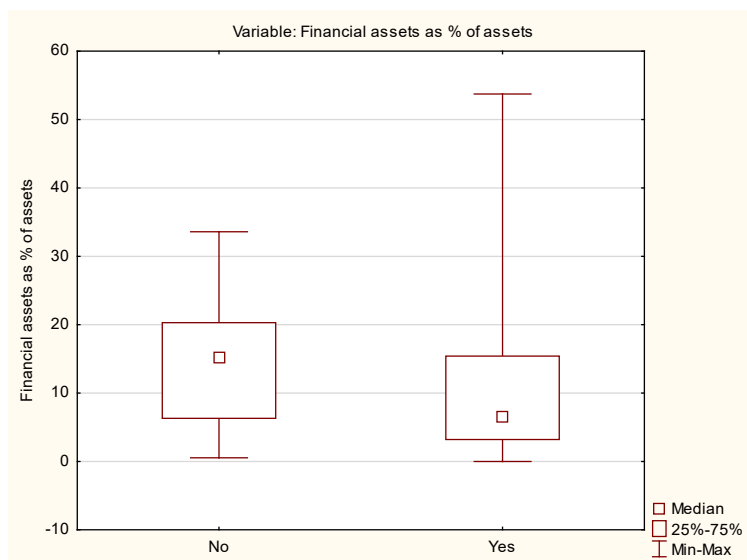


Figure 2: Mann-Whitney U Test - Financial Assets as % of Assets

Source: own processing

Group 3: Operating performance and cash conversion

The third group focuses on operating profit margin and days sales outstanding (DSO) as a proxy for receivables conversion. Neither indicator displays a statistically significant difference between AI-using firms and non-AI firms. Operating profit margin yields $U = 297$ ($Z = -0.596$; $p = 0.550$), while DSO yields $U = 296.5$ ($Z = 0.605$; $p = 0.544$). The direction of rank differences is modest and inconsistent, indicating that AI use is not associated with observable differences in operating profitability or receivables turnover.

Across the six indicators, statistically significant differences are detected for two measures: the administrative cost ratio (higher among AI-using firms) and financial assets as a share of total assets (higher among non-AI firms). The remaining indicators (personnel cost ratio, cash ratio, operating profit margin, and DSO) do not exhibit statistically supported differences between the groups.

5 Discussion

The observed pattern is consistent with a scenario in which AI adoption within firms that already have established controlling is reflected initially in organizational and structural adjustments rather than in immediate improvements in traditional performance metrics. The higher administrative cost ratio among AI-using firms may indicate early-stage investments and operating expenses associated with AI-related implementation, integration, data governance, external services, training, and the development of analytical support routines. This interpretation is consistent with the automation–augmentation perspective, which suggests that AI adoption often brings additional coordination, governance, and accountability demands that can increase overhead-type costs, particularly in the early stages of implementation (Raisch & Krakowski, 2021). These costs can be visible sooner than any resulting productivity or profitability gains, which may require more time to materialize and may depend on the depth and scope of AI use. In line with digital transformation research, performance improvements typically materialize only when technological adoption is complemented by process redesign and organizational change, which implies that short-term accounting effects may be weak even when implementation activity is substantial (Vial, 2019; Verhoef et al., 2021).

The finding that non-AI firms exhibit a higher share of financial assets in total assets suggests a difference in balance-sheet composition and potentially in liquidity-buffer strategies or capital allocation preferences. Such a pattern resonates with capability-based arguments that AI-related value creation often requires resource reallocation toward data, systems, and complementary routines, which may temporarily reduce the relative weight of liquid financial assets on the balance sheet (Mikalef & Gupta, 2021). One plausible interpretation is that AI-using firms allocate relatively less of their asset base to financial instruments, possibly because resources are directed toward operating assets, process reconfiguration, or digital capability building. Related evidence from financial economics links AI investment to firm growth and innovation outcomes (Babina et al., 2024), which is compatible with the notion that firms pursuing AI may prioritize capability-building investments over holding a larger share of financial assets. At the same time, the absence of statistically significant differences in operating profit margin and DSO implies that, in this dataset, AI use does not translate into immediately observable advantages in operating profitability or receivables conversion. This reinforces the notion that the

short-term effects of AI adoption may be complex and may involve trade-offs, such as higher administrative costs in exchange for capabilities that could yield benefits over a longer horizon.

At the same time, the results should be interpreted with caution with respect to causality. The empirical design identifies statistically significant differences between AI-using and non-using firms, but it does not allow a causal conclusion that AI use directly caused the observed differences in administrative cost intensity or asset structure. It is also possible that firms with specific organizational characteristics, higher managerial sophistication, stronger digital orientation, or different investment priorities are more likely to adopt AI in the first place. In this sense, AI use may be both a potential driver of financial and organizational change and an indicator of broader transformation processes already taking place within the firm. The findings therefore demonstrate association rather than causation. Establishing causal effects would require longitudinal data, more detailed information on the timing and intensity of AI implementation, and additional controls for firm size, sector, digital maturity, and strategic orientation.

These results provide a coherent narrative: within controlling-enabled firms, AI use appears more strongly associated with differences in administrative cost intensity and asset-structure characteristics than with short-term operating performance. This supports the view that early-stage AI adoption may be reflected in the cost base and balance-sheet configuration before it is reflected in conventional profitability or working-capital outcomes.

The findings also provide practical implications for managers and controllers. For practitioners implementing AI in controlling, the results suggest that AI adoption should not be assessed only through immediate improvements in profitability or working-capital efficiency. In the early stages, AI use may be associated with higher administrative costs due to system integration, data preparation, process redesign, employee training, external services, and governance requirements. Controllers should therefore distinguish between short-term implementation costs and potential long-term benefits, such as faster reporting, improved forecasting, better analytical support, and more timely managerial information. Managers should also ensure that AI tools are embedded into existing controlling routines and supported by clear responsibilities, data quality management, and evaluation criteria. The absence of

significant differences in operating profit margin and DSO further indicates that AI adoption alone does not automatically lead to superior financial performance; its benefits depend on how effectively it is integrated into decision-making and organizational processes.

Finally, the findings speak directly to recent calls in the accounting and management accounting literature for empirically linking AI-related adoption to observable firm outcomes using financial statement data, including the documentation of non-effects and early-stage cost patterns (Abbas, 2025; Stratopoulos & Wang, 2025).

6 Conclusion

This paper examined whether firms with established controlling differ in selected accounting-based indicators depending on whether they report using AI-related elements. Across the six indicators grouped into cost structure, liquidity-related asset structure, and operating performance/cash conversion, statistically significant differences were observed for two measures. First, AI-using firms exhibited a higher administrative cost ratio, suggesting that AI adoption is associated with a higher administrative cost burden relative to operating revenues in the short run. Second, non-AI firms showed a higher share of financial assets in total assets, indicating differences in balance-sheet composition and potentially in liquidity-buffer strategies or capital allocation preferences. In contrast, personnel cost ratio, cash ratio, operating profit margin, and days sales outstanding did not show statistically supported differences between AI-using firms and non-AI firms.

This contributes evidence that early-stage AI adoption may involve observable organizational and financial-structural adjustments, while performance effects in core profitability or working-capital metrics may require longer observation windows, more granular measures of AI intensity, or additional controls for firm heterogeneity.

This study has several limitations. First, the final analytical sample is relatively modest, which limits the generalizability of the findings and reduces the statistical power of the analysis. Second, the study is based on cross-sectional data, and therefore it does not allow causal inference. The observed differences should be interpreted as associations between reported AI use and selected accounting-based indicators, not as proof that AI adoption directly caused these differences. Third, AI

use is measured as a binary variable, which does not capture the intensity, maturity, functional scope, or specific application of AI in controlling. Future research should therefore use larger samples, longitudinal data, and more detailed measures of AI adoption to examine whether and under what conditions AI-enabled controlling contributes to improved financial performance over time.

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FROM REPORTING TO TRANSFORMATION: A REVIEW OF AI TOOLS ENABLING SUSTAINABILITY GOVERNANCE ACROSS MULTI-TIER SUPPLY CHAINS

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This paper deals with the topic of artificial intelligence tools that have the capacity to assist with sustainability governance in multi-tier supply chains. These tools in the sustainability sector in general are meant to cut costs and enable small and medium enterprises and lower-tier suppliers to get access to best practices, streamline their sustainability efforts, and create universally comparable outputs. The added value of our research is to categorize existing tools, to identify potential gaps, and to enable users to understand the tools with the highest impact. We collect available solutions by a combination of desk research and interviews of industry experts from various levels of supply chain. We evaluate them by their capability to overcome five main challenges – data beyond simple reporting and manual collection, reach beyond Tier 1 suppliers, usability by small enterprises, involvement of artificial intelligence, and tools having an accessible cost. Having such an overview will assist low-key users with less resources to easily tap on existing solutions without large barriers.

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1 Introduction

There have been visible signs of accelerating climate change in Europe, most visibly temperature in Southern European countries such as Greece has been breaking records in past years (Giannaros et al., 2023) or precipitation and drought extremes in other parts (Matanó et al., 2024). Such changes have a fundamental impact on multiple dimensions of the economy and people's lives. For example, agriculture output in multiple EU countries has been impacted by droughts, and larger impacts are yet expected to come (Bolla et al., 2024). Excessive use of electricity during hot summers is taking a toll on aging energy infrastructure (Sammelmann, vom Scheidt, 2025). The impact of climate change in Europe is expected to be roughly double as compared to the global average (UN, 2023).

Hans Joachim Schellnhuber, the founder of Potsdam Institute for Climate Impact Research noted that implementing artificial intelligence (AI) will be critical in combating climate change (Rockström et al., 2017, Fan et al., 2025; Rolnick et al., 2019). While there have been tremendous efforts to combat climate change, the recent rise in AI has given new hope to this powerful tool in the area of climate adaptation and mitigation while it also brings about certain drawbacks like energy consumption (Klesel and Messer, 2026). According to Schellnhuber (1999), there is a tipping point in climate change soon to come. AI tools can help to detect this tipping point (Bury et al., 2021). Due to the non-linear nature of the earth system, modelling of this system has been prohibitively expensive, unless the emergency of AI gives people hope to be able to calculate it at a reasonable cost (Pathak et al., 2018). With new AI tools, it became possible to realistically estimate benefits of renewable energy as compared to maintaining the status quo and propose a replacement plan (Algburi, 2025; Khan, 2026).

Global supply chains are the building block of the world economy and similarly, the joint strength of the actors within them can serve to combat climate change (Vieira et al., 2024). It is therefore very important to be able to implement AI solutions in the supply chains to combat climate change (Ren et al., 2025). Yet, the main difficulty lies in the fact that the world economy is getting increasingly fragmented with more complex supply chains spanning sectors, continents and independent entities which deal with each other at arm's length (Li et al., 2025). One particular problem stands out in these fragmented supply chains; that is, different firms along the supply chain

have become digitally uneven. Large corporations with large resources have access to a plenty of digital tools including AI at their disposal, while lower tier smaller firms struggle to cope with the pace. For example, manual entry of data becomes a bottleneck for system optimization (Ayinaddis, 2025; OECD, 2025). Asymmetry prevents the supply chains as a whole from achieving their full potential in combating climate change. Similarly, companies dealing at arm's length have limited motivation to share their internal data as doing so creates risks to expose their know-how (Zaheer, Trkman, 2017).

In this paper, we aim to exploit this research gap. We intend to find avenues to enable AI usage across supply chains to handle sustainability transformation. That means, utilizing AI not only to collect data and undergo reporting processes, but also to help the actions to be performed. Secondly, we go beyond the simple notion of Tier 1 suppliers that can be directly controlled by the buyers. We rather understand supply chains as entire complex units of analysis where all involved parties play a role. Thirdly, we explore how AI tools can help to reduce reporting and transformation costs to lower-tier suppliers and small and medium enterprises (SMEs).

The paper is structured as follows. In the literature review, we explore the situation within today's supply chains, identify the hurdles and issues associated with sustainability reporting at transformation at multiple levels of supply chains, and check in which tasks could AI tools help the entities to reduce costs and enable action. In the analysis, we identify eleven main categories of AI tools and see how the best tools in each category can do to overcome the five main issues associated with categories of AI tools and see how the best tools in each category can do to overcome the five main issues associated with sustainability reporting and transformation across supply chains. Methodologically, after collecting data on available tools, we seek expert opinions and independent grading of three different supply chain student groups to double check the evaluation.

2 Literature review

2.1 Complex supply chains and requirements propagation/cascading

The complexity inherent for today's supply chains generate important barriers for any innovation adoption, reduce information flows and its speed, and increase transaction costs. Moreover, the incentives are misaligned as each tier of supply chain can be controlled by a separate business entity. In modern multi-tier supply chains, its total carbon footprint is largely decided by energy intensive lower tiers (Tachizawa & Wong, 2014; Wilhelm et al., 2016; Sauer & Seuring, 2023). In other words, Scope 3 of the emissions as mandated by the Greenhouse Gas Protocol (World Resources Institute, 2011). Therefore, the supply chain governance needs a reliable and robust propagation toolbox to go beyond the Tier 1 often dominated by large corporations. This toolbox consists of cascading the code of conduct (Jiang, 2009), monitoring the conduct with regular auditing (Locke et al., 2007) and legally binding sustainability related clauses in written contract (Hoejmose & Adrien-Kirby, 2012). However, despite all the efforts, data acquisition continues to be a major hurdle to achieve full potential of the system (Busch et al., 2022; Matthews et al., 2008). Kim et al. (2022) have also discovered that the lower in the supply chain we go the less green supply chain management practices are applied unless resources and/or incentives are available. These important transaction costs are one of the arguments we aim to address.

2.2 Main hurdles or issues

Low completeness and inconsistent quality of sustainability data is frequently reported as a major issue (Kolk, 2008; Ioannou & Serafeim, 2015). The lack of various resources has caused many SMEs to be unable to effectively participate in the digital transformation (Johnson & Schaltegger, 2016, Mittal et al., 2018; Eller et al., 2020), which also results in lack of standardised data essential for involvement (Rai et al., 2006; Sanders, 2007).

Johnson & Schaltegger (2016) explained how SMEs with limited resources face considerable internal costs when implementing sustainability reporting. This includes data collection, costs of analysis, but also transaction costs – getting advisory services on legal requirements, training, communicating with clients who

are requesting such information, and many others. Where large companies have specialized people handling these tasks, SMEs tend to manage everything centrally within the general management team (Desouza and Awazu, 2006). In addition, duplication of data due to lack of harmonizing standards becomes an external cost burden for these companies (Locke et al., 2007; Soundararajan & Brown, 2016) while there are seldom universal authorities who would control the reporting among various entities and ensure there is no double counting or analysis loopholes. Choi & Hong (2002) and Borgatti & Li (2009) illustrated that governance in multi-tiered supply chains is lagging precisely where it is needed the most.

Among the largest issues, we have identified the following: associated internal and external costs (Rudzioniene, Bazdzius, 2023), topics and issues requested are actually not material for SMEs (Setyaningsih et al., 2024; Steidle et al., 2025), multi-tier analysis is not enabled (Grimm et al., 2023), data is sometimes collected and input manually which brings additional administrative costs (Troshani, Rowbottom, 2024) and AI and other automated systems might or might not be involved in the operations of the SMEs (Mustafa et al., 2025). We see an opportunity for the SMEs to search for tools that enable them to report sustainability data easier so they become more reliable players in the supply chains and partners to their larger clients.

2.3 Overcoming hurdles with AI

The issues mentioned above can now be effectively addressed because with AI, automated data extraction and reliable estimations where data is missing have both become feasible (Baryannis et al., 2019; Busch et al., 2022). AI also lowers participation cost for SMEs (Brynjolfsson et al., 2018)

AI can be useful and reduce costs mostly in the following cases, or tasks: data extraction (Spillias et al., 2025), supply chain mapping (Adegboye et al., 2024; Belu, Marinoiu, 2025), sustainability reporting (Ameh, 2024; Mustafa et al., 2025), dashboards (Akter, Kudapa, 2024), footprint calculation in logistics or in general (Frikha, Mrad, 2025; Huang, Mao, 2024), future prediction (Nweje, Taiwo, 2025), risk assessment (Boone et al., 2025; Zigiene et al., 2022), supplier selection process (Agarwal et al., 2019; Lau et al., 2006, Nida, 2025), logistics optimization (Boute, Udenio, 2022; Shawon et al., 2025), supplier communication and training (Boison et al., 2025) and audit targeting (Rainy, Chowdhury, 2024; Vaghani, 2024). These can

be summarized in three main categories: data intelligence and visibility (data extraction, supply chain mapping, sustainability reporting, dashboards, calculation tools), risk identification and prioritization (prediction tools, risk management), and governance and accountability (supplier selection, logistics optimization, supplier communication and training, audit targeting). Overall, we build the conceptual model of AI involvement as specified in Figure 1 below.

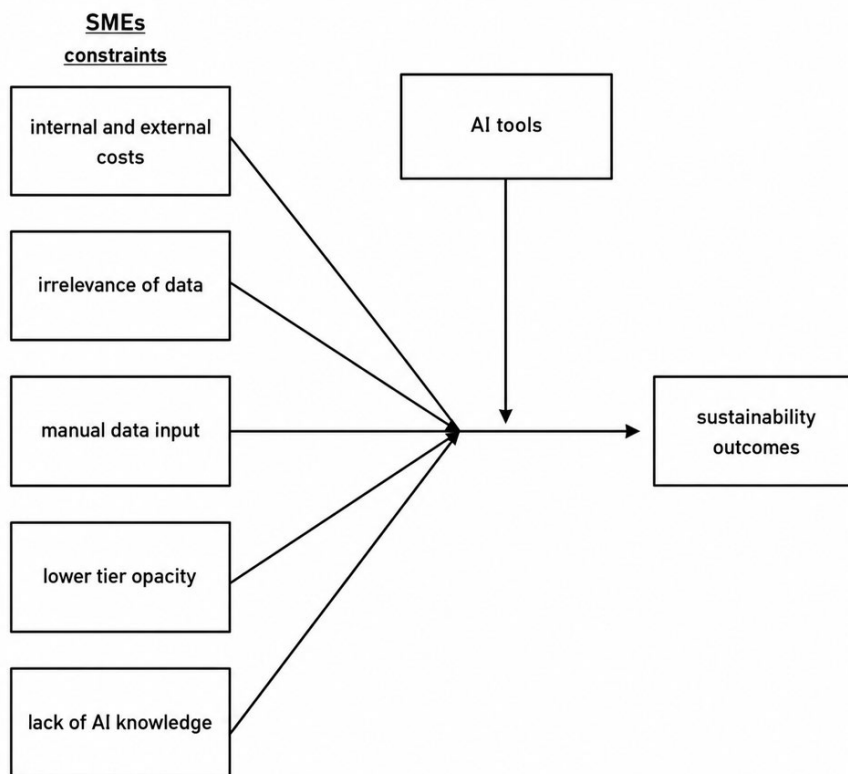


Figure 1: Relationship of SME constraints, AI tools and sustainability outcomes

Source: own elaboration

We listed potential settings where AI can be used to reduce the barriers and improve the sustainability outcomes at lower costs than ever before. Especially in situations where the transaction costs mean a large proportion of the final cost (i.e. for one-off requests and small-scale endeavors, which is all typical for SME settings), the moderating effect of an effective use of AI tools can be enormous.

3 Methodology and data

The methodology of this paper is a desk review of available AI tools. The data themselves are organized in 11 categories of tools (as reviewed in Table 1 below). The categories refer to the main tasks that AI can perform based on literature review. For each category, sample size refers to the number of individual tools, mostly in the form of software solutions offered to sustainability professionals and companies handling sustainability information.

Table 1: List of categories for tool evaluation

Category	Content	Sample size (n)
1	Data extraction	9
2	Supply chain mapping	6
3	Sustainability reporting in supply chains	9
4	Dashboards	9
5	Calculation tools	8
6	Prediction tools	9
7	Risk management	8
8	Supplier selection	9
9	Logistics optimization	9
10	Supplier communication and training	9
11	Audit targeting	10

Source: own elaboration

For each of the tools, five basic questions were asked to our student analysts to evaluate its fit (as shown in Table 2). The questions relate to the issues that SMEs normally face, and results from the literature review above (cost, relevance for SMEs, multi-tier analysis is enabled, automated data input, AI involvement). For each question, we already demonstrate the average score attained in our research (on a scale 1, meaning lowest/non-existent to 10, meaning highest/fully available).

Table 2: List of questions for tool evaluation

Question	Content	Average score
1	Are there discounts for SMEs? (1-10)	5,00
2	Is it suitable for small suppliers? (1-10)	6,43
3	Is the data input manual or automatic? (1=fully manual, 10=fully automatic)	8,12
4	Can we analyze data on more supply chain levels? (1-10)	7,43
5	What is the level of AI involvement? (1-10)	8,02

Source: own elaboration

We collected the data through an expert network in the area of sustainability reporting and supply chain professionals over the period 2024-2026. Secondly, an additional source of data was a collective research event handled on 25th February 2026 in Prague, Czechia, by three independent groups of university students in the courses of Supply Chain and International Business Operations – a total of 66 students participated in the evaluation. These groups are diverse culturally as they include Czech students, foreign students mostly from Eastern Europe studying in Czech, and U.S. exchange students studying in English. Yet, they already possess a certain understanding of supply chain management. Each of the groups were working on an independent document, pairs of students worked on various categories. After the collection of data, they graded the results of another pair to strengthen the evaluation. The collected data were structured and filtered for quality by the research team, with specific focus on feasibility. The average scores were assigned to each of the tools so we could evaluate the best three in each category.

4 Results

In Table 3, we can note average scores for each of the categories involved and the questions evaluated. Each company has received at least 2 different scores. On some occasions even up to six scores were assigned in cases where the same AI tool was listed by various pairs of students. We see that Question 1 received ambiguous results, where some companies offer significant discounts or even free usage for SMEs, while others use the same pricing. Similarly, the tools did not receive a very high score on the suitability for SMEs use (Question 2), especially in the categories of calculation tools, prediction tools, risk management and audit targeting where it scored below 6. The highest scores were for Questions 3 and 5, i.e. data is usually input automatically and AI is very much involved in the process. Interestingly, on Question 4 about the ability to handle multiple tiers of suppliers at the same time, calculation tools, which are one of the most prominent category with a large spotlight by the users, received the lowest scores.

Table 3: Average scores for each category and question.

Category	Q1	Q2	Q3	Q4	Q5
Data extraction	6,17	7,19	7,44	7,63	7,75
Supply chain mapping	4,36	6,81	9,49	7,52	8,11
Sustainability reporting in supply chains	5,72	7,00	9,39	7,00	7,89
Dashboards	6,67	6,94	9,56	7,28	7,89
Calculation tools	4,35	5,95	7,78	6,39	7,00
Prediction tools	4,28	5,72	6,61	7,94	8,22
Risk management	3,84	5,59	8,94	7,63	8,28
Supplier selection	4,93	6,50	7,74	7,22	7,87
Logistics optimization	5,17	6,44	7,50	7,44	8,44
Supplier communication and training	4,94	7,17	6,39	7,81	8,44
Audit targeting	4,58	5,45	8,45	7,83	8,28
OVERALL	5,00	6,43	8,12	7,43	8,02

Source: own calculation

Below in Table 4, we note the best three tools for each of the categories. Overall, the tool Flowgenius received the highest score of all – 9,20. It was nominated for the category of dashboards. 10 more tools received a score above 8,00 and overall, the best scores were also in the category of dashboards (overall, 7,67), mostly caused by the fact that these tools offer the most friendly prices to SMEs. On the other hand, calculation tools received the worst scores (on average, 6,29), followed by prediction tools (6,55) and supplier selection (6,85).

There were some tools which appeared repeatedly (demonstrated in Table 5). That means they are able to handle multiple tasks within one platform which could create opportunities for SMEs to reduce transaction costs, specifically for training, onboarding and initial data collection or integration with their internal systems, even though they were not necessarily graded as the most useful in individual categories. IntegrityNext was listed in five categories and Ecovadis in four of them. This does not mean that the other tools cannot handle more tasks than listed, it just means they were not named among the top three for the given category by anyone. This is a nice demonstration that our study's categorization, while robust, may not fully capture the functional integration offered by certain platforms, which could be a fruitful stream for future research.

Table 4: Top three tools for each category and score.

Category	1st	2nd	3rd
Data extraction	Prewave 8,30	Parseur 7,80	Sourcemap 7,60
Supply chain mapping	Everstream 7,80	Ecovadis 7,75	Resilinc 7,50
Sustainability reporting in supply chains	Normative 8,90	Greenomy 8,20	Greenly 8,10
Dashboards	Flowgenius 9,20	MS Power BI 8,30	Novata 8,10
Calculation tools	Normative 7,80	Worldfavor 7,70	IntegrityNext 7,55
Prediction tools	GMDH Streamline 8,10	DATUP 7,70	KINAXIS 7,20
Risk management	Sardine 7,90	IntegrityNext 7,60	Lasso Security 7,20
Supplier selection	FairSupply 7,67	GEP Smart 7,50	Worldfavor 7,30
Logistics optimization	Slimstock 8,00	PTV Logistics 8,00	Sourcemap 7,50
Supplier communication and training	SmartCat 8,40	Inventive AI 7,90	Kodiak Hub 7,70
Audit targeting	BeSirius 8,00	Prewave 7,80	Versed AI 7,60
OVERALL	Flowgenius 9,20	SmartCat 8,40	MS Power BI 8,30

Source: own calculation

Table 5: Most versatile tools.

Tool	Number of categories
IntegrityNext	5
Ecovadis	4
FairSupply	3
SourceMap	3
Interos	3
Everstream Analytics	2
Makersite	2
Prewave	2
Sweep	2
Resilinc	2
Wordfavor	2

Source: own calculation

5 Conclusion

The objective of the paper was to evaluate existing AI tools relevant for sustainability reporting and transformation within complex supply chains. We have identified three main areas of tools engagement – data intelligence and visibility, risk identification and prioritization, governance and accountability – with eleven main tasks where AI can importantly serve as an enabler to overcome five main challenges – costs, information irrelevance, manual data input, lack of visibility beyond Tier 1, and lack of AI implementation.

Results show that most tools use automated data collection and enable large deployment of AI. The results are fairly optimistic, but not entirely conclusive when it comes to the capability to analyze a full supply chain at all its tiers. The lowest scores were seen on the usefulness of the tools in SME contexts and their availability when it comes to costs. Therefore, some barriers to AI implementation in SMEs still remain. Thematically, it looks like calculation and prediction tools are the least suitable for usage by SMEs and lower tier suppliers, while on the other hand dashboards, sustainability reporting and data extraction tools received the best scores – all in the area of data intelligence and visibility. This implies that the largest potential for use by SMEs still lies in the area of descriptive tasks rather than analytical and decision support tools.

There are important business implications of our paper. Any company regardless of its size can refer to our overview and get the best tool that is relevant for their needs. Some tools even have the ambition to cover multiple sustainability-related tasks at a time. The transaction costs that the user firm needs to sacrifice and the time needed to set up the system can be reduced this way. Overall, using the tools might bridge the communication and expectation gaps between lead firms and their supply chain regardless of the tier in which the supplier is located.

Limitations of our research are clear – the mentioned tools are subject to economic development and might change in quality over time, or they might be removed from the market. However, we believe that our analysis serves as an important snapshot of the AI tool scene in the sustainability reporting and sustainability transformation in 2026. For future research, we would recommend diving deeper into the specific features of each tool, and to understand what is the best practice or necessary

functionality for a given category. Also, it would be worthwhile to expand the evaluation process to increase its robustness. Lastly, SMEs needs in the area of sustainability should be explored to tailor potential innovation in the market to their needs.

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INTEGRATING ZERO-WASTE MANAGEMENT INTO CORPORATE GOVERNANCE: AN APPLICATION OF THE MER MODEL OF INTEGRAL MANAGEMENT AND GOVERNANCE

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This paper examines how the MER model of integral management and governance (MER model) can be applied to assess the integration of zero-waste management into corporate governance. It evaluates whether waste reduction is addressed merely as an operational activity or embedded across political, strategic, and operational levels of management. Methodology: The study adopts a qualitative multiple case design based on content analysis of annual reports of selected companies. Waste-related disclosures (pursuant to ESRS requirements) were evaluated using the MER model to assess governance-level integration and cross-level coherence. Findings: The results indicate that companies predominantly address waste management at the operational level, while strategic integration and embedding at the political level remain limited. Value: The study demonstrates how the MER model can be applied to analyse zero-waste management as a governance issue rather than solely as a technical or environmental practice.

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1 Introduction

Corporate responsibility has evolved from focusing on moral obligations of business leaders (Bowen, 1953) to encompassing economic, legal, ethical, and discretionary responsibilities (Wood, 1991; Dahlsrud, 2008). Over time, CSR moved from voluntary actions to a more strategic, governance-oriented approach (Chandler & Werther, 2013; Latapí Agudelo et al., 2019).

Within this evolution, sustainability reporting has become a central mechanism for institutionalising corporate responsibility. The European Union has progressively strengthened non-financial disclosure requirements, moving from the Non-Financial Reporting Directive (NFRD) toward the Corporate Sustainability Reporting Directive (CSRD). This regulatory shift reflects a transition from transparency-focused disclosure toward structured, governance-integrated sustainability reporting (Björklund, 2021; Cuomo et al., 2022; Primec & Belak, 2022). Under the CSRD framework, sustainability is no longer treated as a peripheral reporting exercise but as a governance obligation embedded within corporate strategy, risk management, and oversight structures (Primec, 2024; Villiers, 2022).

In this broader regulatory and theoretical context, waste management represents a particularly illustrative field of analysis. Waste-related disclosures are commonly included in sustainability reports and environmental sections of annual reports. However, these disclosures often focus on quantitative indicators such as recycling rates, waste volumes, and efficiency improvements. While such measures are important, they may reflect predominantly operational compliance rather than systemic transformation. The zero-waste concept is frequently associated with operational waste reduction practices and circular production models aimed at minimising material disposal. However, in the context of corporate governance, zero-waste should not be understood solely as a technical environmental management approach. Rather, it represents a governance ambition that challenges firms to integrate resource responsibility into corporate purpose, strategic orientation, and operational execution. From this perspective, zero-waste does not necessarily imply the immediate elimination of all waste streams, but instead reflects the degree to which waste management is institutionally embedded within governance structures and aligned across managerial levels. Accordingly, this study does not evaluate the technical implementation of zero-waste systems or the

performance effectiveness of waste reduction measures. Instead, it assesses the extent to which waste management is vertically integrated within corporate governance architecture in line with the regulatory logic of ESRS E5. Zero-waste is therefore conceptualised as an indicator of governance coherence rather than as a purely operational environmental outcome. The zero-waste concept, rooted in sustainability and circular economy thinking, challenges firms to go beyond incremental waste reduction and redesign resource flows and business models in a systemic manner. From a governance perspective, zero-waste cannot be reduced to operational environmental management; it requires integration across corporate values, long-term strategic orientation, and operational processes. In other words, zero-waste implementation constitutes not merely an environmental initiative but a test of organisational coherence and governance alignment. Stakeholder theory further reinforces this perspective. Firms operate within networks of stakeholders whose expectations increasingly include responsible resource management and environmental stewardship (Freeman, 1984, 1994, 2001; Friedman & Miles, 2002). Contemporary approaches emphasise company stakeholder responsibility as an integrated governance philosophy rather than a reactive compliance mechanism. Consequently, waste management and circular practices become elements of stakeholder accountability rather than purely technical functions (Čufar & Primec, 2022; Freeman & Velamuri, 2021).

Despite the increasing regulatory pressure and normative expectations, prior research indicates that sustainability disclosures may remain symbolic or fragmented if not embedded within governance structures (Jamali & Mirshak, 2007; Sandhu & Kapoor, 2010). The transition from voluntary CSR toward mandatory sustainability reporting raises the question of whether companies are achieving genuine vertical integration of sustainability across managerial levels or whether reporting improvements mask structural fragmentation. This paper addresses this gap by applying the MER model of integral management and governance as an analytical framework to examine zero-waste integration. The MER model of integral management and governance distinguishes between political, strategic, and operational levels of management and emphasises the necessity of alignment among them for organisational coherence. When applied to sustainability governance, this framework enables systematic assessment of whether environmental initiatives are embedded in corporate purpose, strategic planning, and operational execution in a consistent manner. The aim of this paper is to examine how the MER model of

integral management and governance can be applied to analyse and enhance the integration of zero-waste management principles into corporate governance and business models. Empirically, the study focuses on nine Slovenian companies that fall within the initial scope of the CSRD applicability and currently disclose sustainability-related information in their annual or separate sustainability reports. Through qualitative content analysis, the research evaluates the scope and level of integration of waste-related disclosures within corporate reporting (Belak et al., 2014; Čufar et al., 2026; Primec, 2024; Villiers, 2022).

The study is guided by the following research questions:

- RQ1: To what extent do Slovenian companies report data and disclosures related to waste management in their annual and sustainability reports?
- RQ2: How can the application of a multi-level governance framework (political, strategic, and operational) contribute to assessing and enhancing the coherence of zero-waste integration within corporate governance structures?

By reframing zero-waste management as a governance coherence issue rather than merely an environmental performance indicator, this study contributes to the evolving literature on CSR institutionalisation and sustainability reporting. It also provides practical implications for companies navigating the transition from compliance-based disclosure toward structurally embedded sustainability governance (Primec, 2024; Villiers, 2022).

2 Theoretical background

2.1 Evolution of CSR and Institutionalisation of Sustainability Reporting

CSR has historically evolved from normative reflections on the moral obligations of business leaders toward society to structured governance and accountability frameworks. Bowen (1953) first articulated the idea that business decisions should be aligned with societal values and expectations, thereby positioning corporations as moral actors embedded in broader social systems. This early normative perspective conceptualised responsibility as an ethical duty rather than a strategic instrument. Later, Wood (1991) reconceptualised CSR through the lens of corporate social performance, distinguishing between principles of responsibility, processes of

responsiveness, and observable social outcomes. This shift transformed CSR from an abstract ethical aspiration into a structured organisational framework capable of assessment and evaluation (Bowen, 1953; Wood, 1991).

The conceptual expansion of CSR over time has resulted in a plurality of definitions encompassing environmental, social, stakeholder, economic, and voluntariness dimensions. Dahlsrud (2008), through an analysis of multiple CSR definitions, demonstrated that despite terminological diversity, stakeholder orientation and environmental responsibility consistently appear as core dimensions. This conceptual consolidation indicates that CSR gradually moved from discretionary philanthropy toward systemic integration of environmental and social considerations into business activities. The historical evolution further reflects a transition from peripheral corporate initiatives to governance-embedded sustainability management integrated into organisational decision-making structures (Dahlsrud, 2008; Latapí Agudelo et al., 2019). Stakeholder theory provided the theoretical foundation for this structural transition. Freeman (1984) introduced the stakeholder approach as a strategic management framework, arguing that firms must create value for a broad network of stakeholders rather than exclusively for shareholders. Subsequent developments extended stakeholder theory beyond strategic analysis into governance and accountability domains (Freeman, 1994, 2001). The recognition that corporations operate within complex stakeholder ecosystems implied that sustainability issues (including environmental responsibility) could not remain peripheral operational concerns. Rather, they became integral to corporate legitimacy and long-term viability. Later conceptualisations framed company stakeholder responsibility as a governance philosophy embedded in strategic decision-making and organisational identity (Freeman & Velamuri, 2021; Friedman & Miles, 2002).

The institutionalisation of CSR accelerated as regulatory actors increasingly formalised expectations regarding corporate transparency and accountability. At the European level, CSR was initially promoted as a voluntary concept. The European Commission's Green Paper (2001) defined CSR as the voluntary integration of social and environmental concerns into business operations and stakeholder interactions. This framing reflected the prevailing assumption that corporate responsibility should remain self-regulated and market-driven. However, the growing recognition of environmental challenges, financial crises, and governance failures gradually shifted

the debate toward the need for structured disclosure obligations and regulatory oversight (European Commission, 2001; Björklund, 2021). The introduction of the NFRD marked a turning point in this evolution, as it transformed CSR from a voluntary commitment into a mandatory disclosure requirement for large public-interest entities. The NFRD required companies to disclose information on environmental, social, and governance matters, thereby institutionalising sustainability reporting within corporate accountability frameworks. Nevertheless, empirical studies reveal that the NFRD produced heterogeneous reporting practices and limited comparability across firms, partly due to flexibility in interpretation and the absence of uniform standards (Cuomo et al., 2022; Björklund, 2021). The transition toward the CSRD represents a qualitative regulatory shift from transparency-oriented reporting toward governance-integrated sustainability management. The CSRD strengthens standardisation, expands the scope of obligated entities, and explicitly connects sustainability disclosures to strategy, risk management, and governance oversight. In doing so, it reinforces the expectation that sustainability issues (such as environmental resource management and waste reduction) must be embedded within corporate governance structures rather than addressed solely at the operational level (Primec & Belak, 2022; Primec, 2024; Villiers, 2022). This regulatory evolution reflects the broader theoretical transformation of CSR from political level responsibility to institutionalised governance architecture. Sustainability reporting is no longer conceived merely as a reputational communication tool but as a structural mechanism through which corporate governance systems are evaluated, monitored, and aligned with societal expectations. Consequently, contemporary CSR is increasingly understood as a governance-integrated framework that links corporate purpose, strategic orientation, and operational implementation within a coherent accountability system (Čufar, 2025; Latapí Agudelo et al., 2019; Primec & Belak, 2022).

2.2 Corporate Governance and Strategic CSR Integration

Strategic CSR literature emphasises that sustainability must be integrated into long-term value creation and competitive positioning rather than treated as an ancillary compliance activity. Porter and Kramer (2006) argue that CSR can contribute to competitive advantage when aligned with core corporate strategy, particularly when firms identify intersections between societal needs and business opportunities. In this perspective, sustainability initiatives are not external constraints but potential

sources of innovation, differentiation, and productivity improvement. Chandler and Werther (2013) further highlight that stakeholder considerations must be embedded within strategic management processes, as long-term organisational performance depends on maintaining legitimacy and trust across stakeholder networks. Strategic CSR thus represents a shift from reactive responsibility toward proactive integration within competitive strategy (Porter & Kramer, 2006; Chandler & Werther, 2013). From a managerial perspective, corporate sustainability creates value when incorporated into organisational decision-making systems and accountability mechanisms. Camilleri (2014) argues that sustainability strategies are effective only when they are supported by structured planning processes and measurable performance indicators. In a later contribution, Camilleri (2017) emphasises that sustainability must be aligned with corporate governance systems, managerial incentives, and business model design to ensure consistency between declared commitments and operational realities. Without integration into planning, budgeting, and performance management systems, sustainability remains symbolically endorsed but operationally marginal. This implies that strategic CSR requires not only goal-setting but also systemic embedding within organisational control structures (Camilleri, 2014; Camilleri, 2017). The distinction between substantive and symbolic integration is particularly relevant in sustainability reporting research. Empirical studies demonstrate that corporate disclosures may be motivated by legitimacy concerns rather than by transformative intent. Jamali and Mirshak (2007) show that CSR initiatives in developing contexts often remain fragmented when not supported by internal governance mechanisms and strategic alignment. Similarly, Sandhu and Kapoor (2010) find that voluntary CSR disclosures may function as reputational signalling tools, especially in the absence of formalised governance accountability. These findings indicate that the presence of sustainability reporting does not necessarily imply strategic integration, rather, it may reflect external pressure management or impression management strategies (Jamali & Mirshak, 2007; Sandhu & Kapoor, 2010). The strengthening of sustainability reporting requirements under the CSRD aims to reduce such fragmentation by embedding sustainability within governance oversight, risk management structures, and strategic accountability mechanisms. Primec and Belak (2022) argue that the CSRD introduces legal and managerial demands that extend beyond disclosure volume toward systemic integration within corporate governance. Similarly, Primec (2023) emphasises that sustainability reporting under the new EU framework functions as a legal instrument shaping governance practices rather than merely

documenting performance. Villiers (2022) further highlights that the evolving EU regulatory framework reflects increasing complexity and interconnection between reporting, due diligence, and accountability mechanisms. This institutionalisation signifies a broader evolution from voluntary CSR initiatives toward governance-integrated sustainability architecture embedded within corporate oversight and strategic management systems (Čufar et al., 2025; Primec & Belak, 2022; Primec, 2024; Villiers, 2022).

2.3 Multi-Level Governance in Political, Strategic, and Operational Alignment

From a governance perspective, sustainability integration requires vertical alignment across managerial levels, ensuring coherence between corporate purpose, long-term strategic orientation, and day-to-day operational implementation. Sustainability becomes structurally embedded only when it is reflected consistently across these interconnected governance dimensions rather than confined to isolated environmental initiatives. Vertical alignment represents a core condition for organisational legitimacy and long-term viability within stakeholder-oriented governance systems (Freeman, 1984; Freeman, 2001). At the political level, corporate purpose, values, and governance principles define the legitimacy of business activities within society. Bowen (1953) conceptualised corporate responsibility as alignment between business decisions and societal expectations, thereby establishing the moral foundation of corporate governance. Wood (1991) further developed this perspective by linking principles of corporate responsibility with institutional legitimacy and public accountability. Political integration implies that sustainability principles are explicitly embedded in corporate mission statements, codes of conduct, governance charters, and board-level commitments. When sustainability is anchored at this level, it becomes part of organisational identity rather than a reactive response to regulatory pressure (Bowen, 1953; Wood, 1991). Within the MER model of integral management and governance, the political level refers to corporate purpose, fundamental governance orientation, and value-based legitimacy structures. Integration on the political level also reflects stakeholder-oriented governance logic. If sustainability considerations are incorporated into corporate purpose, they signal recognition of broader stakeholder claims and long-term societal responsibilities. Such embedding transforms sustainability from a discretionary initiative into a foundational governance principle

aligned with stakeholder accountability frameworks (Freeman, 1994; Freeman & Velamuri, 2021).

At the strategic level, sustainability is translated into long-term objectives, competitive positioning, and resource allocation decisions. Strategic CSR frameworks emphasise that sustainability must be integrated into corporate strategies, supported by measurable targets, and aligned with stakeholder expectations to generate long-term value (Porter & Kramer, 2006; Chandler & Werther, 2013). Strategic integration ensures that environmental and social objectives influence capital investment decisions, innovation priorities, supply chain design, and performance management systems. Without such integration, sustainability remains peripheral to core business logic. Strategic alignment further implies that sustainability risks and opportunities are embedded within corporate planning and governance oversight structures. When sustainability objectives are formally incorporated into strategic roadmaps and performance indicators, they gain institutional weight and managerial accountability. In this sense, strategic integration functions as a bridge between political commitments and operational execution, translating values into measurable and actionable corporate objectives (Chandler & Werther, 2013; Porter & Kramer, 2006).

At the operational level, sustainability is implemented through concrete processes, procedures, and measurable indicators. Environmental disclosures such as waste volumes, recycling rates, resource efficiency measures, and emission reductions typically reflect operational integration. These disclosures provide transparency regarding performance outcomes and compliance with regulatory requirements (Sandhu & Kapoor, 2010). Recent reporting research further shows that operational environmental indicators often dominate sustainability reports due to their measurability and comparability (Matuszak-Flejszman et al., 2023).

However, operational measures, while necessary, do not in themselves guarantee strategic or political coherence. The existence of quantitative environmental data does not necessarily imply that sustainability objectives influence corporate purpose or long-term strategic orientation. Operational integration may therefore reflect compliance-based environmental management rather than governance-embedded sustainability transformation (Jamali & Mirshak, 2007). The absence of alignment across political, strategic, and operational levels may result in fragmented

sustainability governance. In such cases, companies report environmental performance indicators without corresponding strategic direction or explicit commitment at the political level. This fragmentation can produce inconsistencies between declared corporate values and observable managerial practices, potentially undermining stakeholder trust and organisational legitimacy (Jamali & Mirshak, 2007; Sandhu & Kapoor, 2010). From an institutional perspective, achieving vertical coherence requires that sustainability considerations permeate governance architecture rather than remain confined to reporting functions. Only when sustainability principles are simultaneously reflected in corporate purpose, strategic objectives, and operational practices can they be considered structurally integrated within corporate governance systems (Primec & Belak, 2022).

2.4 Zero-Waste as a Governance Integration

Waste management provides an illustrative and analytically valuable context for examining multi-level sustainability integration within corporate governance systems. As an environmental issue, waste management is highly measurable, operationally visible, and commonly disclosed in corporate sustainability reporting. Companies frequently present waste-related data in environmental sections of annual or sustainability reports, including total waste volumes, recycling rates, hazardous waste treatment, and efficiency improvements. However, prior research on non-financial reporting indicates that such disclosures often emphasise quantitative metrics and compliance with regulatory requirements rather than demonstrating strategic or governance-level embedding (Björklund, 2021; Cuomo et al., 2022). The dominance of quantitative environmental indicators reflects a broader reporting logic shaped by earlier regulatory frameworks, particularly under the NFRD, where flexibility and comparability limitations encouraged descriptive and performance-oriented disclosures (Björklund, 2021). As a result, waste management is frequently communicated as an environmental management activity aimed at demonstrating transparency and regulatory compliance rather than as a strategic transformation mechanism. This pattern suggests that the presence of waste-related data alone cannot be interpreted as evidence of systemic sustainability integration (Cuomo et al., 2022). If waste management is confined to operational indicators (such as reporting tonnes of waste generated or percentages recycled), it primarily reflects performance reporting rather than governance integration. Operational disclosures demonstrate implementation capacity but do not necessarily indicate

alignment with long-term strategic priorities or corporate purpose. In this sense, operational reporting may signal environmental responsiveness without confirming strategic or embedding (Sandhu & Kapoor, 2010). Strategic integration of waste management would require articulation of long-term waste-reduction objectives, incorporation of circular economy principles into corporate strategy, and alignment of resource efficiency initiatives with value creation logic. Porter and Kramer (2006) argue that sustainability initiatives generate competitive advantage when embedded within strategic positioning and linked to business opportunities. Similarly, Camilleri (2017) emphasises that corporate sustainability must be aligned with business model innovation and long-term planning to create shared value. Therefore, strategic waste integration would imply that resource management influences investment decisions, innovation priorities, and supply chain configuration (Porter & Kramer, 2006; Camilleri, 2017).

Political level integration represents an even deeper level of embedding. It would require explicit recognition of resource stewardship and environmental responsibility within corporate mission statements, governance codes, and board-level commitments. Bowen (1953) conceptualised corporate responsibility as alignment between business conduct and societal expectations, implying that environmental responsibility forms part of corporate legitimacy. Wood (1991) further emphasised that principles of responsibility must be institutionalised within governance systems to ensure coherence between values and performance. Political level integration of waste management would therefore signal that resource efficiency is not merely an operational concern but a foundational governance principle (Bowen, 1953; Wood, 1991). The central analytical challenge, therefore, lies in assessing whether waste-related disclosures represent vertically integrated sustainability governance rather than fragmented environmental reporting. The evolution toward the CSRD strengthens expectations that sustainability matters be embedded within governance oversight, strategic planning, and risk management structures. Primec and Belak (2022) argue that the new EU framework introduces managerial and legal obligations that go beyond disclosure volume toward structural integration. Primec (2023) further emphasises that sustainability reporting under the CSRD functions as a governance instrument shaping corporate accountability mechanisms. Consequently, examining waste management through a multi-level governance lens provides insight into whether companies are transitioning from compliance-oriented reporting toward institutionally embedded sustainability

governance consistent with the regulatory evolution (Primec & Belak, 2022; Primec, 2024).

2.5 ESRS E5 as a Normative Benchmark for Assessing Waste-Related Disclosures

The evolution from voluntary CSR toward governance-integrated sustainability reporting culminates in the adoption of the European Sustainability Reporting Standards (ESRS) under the CSRD framework. Within this architecture, ESRS E5 – Resource Use and Circular Economy establishes a structured and detailed disclosure framework specifically addressing resource inflows, circular economy practices, product design, and waste management (EFRAG, 2025). The objective of ESRS E5 is to ensure that undertakings disclose information necessary to understand their impacts, risks, and opportunities related to resource use and the circular economy. The standard explicitly links environmental resource management with broader governance and risk management obligations under ESRS 1 and ESRS 2 (EFRAG, 2025, p. 3). This linkage reinforces the shift from environmental performance reporting toward governance-integrated sustainability disclosure, consistent with the regulatory transition described by Primec and Belak (2022) and Primec (2023).

Importantly, ESRS E5 structures disclosure requirements across three major dimensions (Rimmel et al., 2025):

1. Policies (DR E5-1)
2. Actions and resources (DR E5-2)
3. Metrics and targets (DR E5-3, E5-4, E5-5)

These dimensions directly correspond to the multi-level governance logic discussed earlier. Disclosure Requirement E5-1 requires companies to describe their policies related to resource use and circular economy, including integration of eco-design and circular principles into key products and services (EFRAG, 2025, p. 4). This requirement reflects the political level, as it concerns formal commitments and governance orientation. Disclosure Requirement E5-2 addresses actions and resource allocation related to circular economy practices (EFRAG, 2025, p. 4). This connects to the strategic level, where sustainability commitments are translated into organisational measures and managerial decision-making structures. Disclosure

Requirements E5-3 to E5-5 introduce measurable targets and quantitative indicators, including (EFRAG, 2025, pp. 4–5; Rimmel et al., 2025):

- Targets related to resource use and circular economy (E5-3),
- Resource inflows, including key materials and secondary resources (E5-4),
- Resource outflows, including product durability, recyclability, and waste streams (E5-5).

Particularly relevant for this study is DR E5-5, which requires disclosure of total waste generated, breakdown between hazardous and non-hazardous waste, proportion of waste diverted from disposal, proportion directed to disposal, and specification of recovery and disposal. The detailed specification of metrics (such as waste streams, diversion rates, and final destination) provides a structured benchmark for evaluating the completeness and depth of corporate waste-related disclosures operations (EFRAG, 2025, p. 5). Furthermore, ESRS E5 explicitly situates the circular economy within broader EU regulatory frameworks, including the Waste Framework Directive and the Circular Economy Action Plan. This demonstrates that waste management is no longer an isolated environmental issue but a regulated governance domain embedded within European industrial and sustainability policy architecture (EFRAG, 2025, p. 3).

From a theoretical standpoint, ESRS E5 operationalises the transition from political level CSR to institutionalised sustainability governance. While earlier CSR frameworks emphasised voluntary alignment with societal expectations (Bowen, 1953; Wood, 1991), ESRS E5 introduces legally anchored, standardised disclosure obligations that structure how sustainability must be reported. This regulatory formalisation strengthens comparability and reduces discretionary interpretative flexibility that characterised earlier reporting regimes under the NFRD (Björklund, 2021; Cuomo et al., 2022). Consequently, ESRS E5 provides not merely a reporting checklist but a normative benchmark for assessing governance integration. In the context of this study, the standard serves as the analytical reference point for evaluating the extent to which Slovenian companies disclose information related to waste management in their annual and sustainability reports. The central empirical objective is therefore not only to identify whether waste-related information is

disclosed, but to assess how comprehensively such disclosures align with the structured requirements of ESRS E5, particularly with regard to (EFRAG, 2025):

- existence of formal policies (E5-1),
- articulation of actions and resource allocation (E5-2),
- presence of targets (E5-3),
- disclosure of resource inflows (E5-4),
- detailed reporting on waste streams and diversion/disposal rates (E5-5).

By positioning ESRS E5 as the evaluative framework, the study bridges governance theory and regulatory practice, enabling systematic assessment of the degree to which corporate waste management reporting reflects emerging EU standards (EFRAG, 2025). Recent empirical evidence suggests that the implementation of ESRS E5 does not automatically result in governance-integrated circular economy management. Reporting practices remain predominantly focused on waste reduction and recycling indicators, while more advanced elements such as value-chain integration, scenario analysis, and financial implications are only partially addressed.

These findings indicate that formal compliance with ESRS E5 disclosure requirements does not necessarily ensure vertical coherence across political, strategic, and operational governance levels. Consequently, a distinction must be made between disclosure completeness and governance maturity. In this context, ESRS E5 functions not only as a reporting framework but also as a diagnostic tool for assessing the depth of circular economy integration within corporate governance structures. While the standard provides a structured disclosure architecture, it does not guarantee that circular economy principles are embedded in corporate purpose or strategic decision-making. Therefore, evaluating waste-related disclosures through a multi-level governance lens enables differentiation between procedural compliance and substantive integration. This reinforces the importance of vertical coherence as a key condition for achieving meaningful circular transformation. (Maas et al., 2025; Wieteska-Rosiak, 2025).

3 Methodology

This study adopts a qualitative multiple case study design to examine the extent and structure of waste management disclosures in relation to the requirements of ESRS E5 (resource use and circular economy). Case study methodology is particularly appropriate for investigating complex organisational phenomena embedded within institutional and regulatory contexts, especially when the aim is analytical rather than statistical generalisation (Yin, 2009). Given that sustainability reporting under the CSRD represents a governance-integrated regulatory framework, qualitative cross-case analysis enables systematic comparison of disclosure practices across companies (Voss, Tsikriktsis, & Frohlich, 2002).

The empirical focus is on nine Slovenian companies that would fall within the initial scope of CSRD applicability and that currently disclose sustainability-related information in their annual or sustainability reports. The regulatory context is central to the research design. The transition from the NFRD toward the CSRD reflects a structural shift from transparency-oriented disclosure toward standardised, governance-integrated sustainability reporting (Björklund, 2021; Primec & Belak, 2022). The CSRD, implemented through the ESRS framework, introduces structured disclosure requirements that connect sustainability information with governance oversight, strategy, and risk management (Primec, 2024; Villiers, 2022).

The analytical benchmark of this study is ESRS E5, which specifies disclosure requirements related to policies (E5-1), actions and resources (E5-2), targets (E5-3), resource inflows (E5-4), and resource outflows, including waste management (E5-5) (EFRAG, 2025). These requirements provide a structured normative framework for assessing the scope and depth of corporate waste-related disclosures. The study relies on publicly available annual reports and sustainability reports for the year 2024. Corporate reports constitute formal accountability instruments through which undertakings communicate sustainability commitments and governance structures to stakeholders (Sandhu & Kapoor, 2010). Content analysis of such reports is widely applied in CSR and sustainability research to evaluate disclosure quality, scope, and managerial orientation (Lajili & Zéghal, 2005).

A qualitative content analysis approach was applied to assess the extent to which companies disclose information corresponding to the individual disclosure requirements of ESRS E5. Each report was systematically examined against the standard's structured requirements, particularly (EFRAG, 2025; Lajili & Zéghal, 2005; Sandhu & Kapoor, 2010):

- existence of formal policies related to resource use and circular economy (E5-1),
- disclosure of actions and resource allocation (E5-2),
- articulation of measurable targets (E5-3),
- reporting of resource inflows (E5-4),
- detailed reporting on waste streams, diversion rates, and disposal practices (E5-5).

To deepen the analytical interpretation, disclosures were additionally categorised according to a three-level governance logic pursuant to the MER model of integral management and governance (political, strategic, operational) (Belak & Duh, 2012). The political level captures policy statements and governance commitments. The strategic level captures long-term objectives and integration into corporate strategy. The operational level captures quantitative waste indicators and implementation measures. This dual-layer framework enables assessment not only of whether companies report required information, but also of how deeply such reporting is embedded within governance architecture (Porter & Kramer, 2006; Sandhu & Kapoor, 2010). Analytical generalisation is pursued by evaluating structural alignment between corporate disclosures and the regulatory expectations embedded in ESRS E5. The objective is to determine whether waste-related disclosures demonstrate emerging compliance with the structured CSRD reporting regime or remain limited to operational environmental reporting (Belak & Duh, 2015; Yin, 2009).

To ensure analytical consistency and transparency, a structured coding scheme was applied. Each company report was systematically evaluated against the disclosure requirements of ESRS E5 (E5-1 to E5-5). Disclosures were classified using a two-level scale: (1) explicitly disclosed and aligned with ESRS requirements and (2) not disclosed. In addition, all identified disclosures were categorised according to the

three governance levels of the MER model of integral management and governance. Disclosures referring to formal policies, governance commitments, or corporate values were classified at the political level. Disclosures related to long-term objectives, targets, and integration into corporate strategy were classified at the strategic level. Quantitative indicators, operational measures, and implementation practices were classified at the operational level. This dual coding approach enabled a systematic comparison across cases and facilitated the assessment of vertical coherence between governance levels. (Čufar et al., 2024; Jamali & Mirshak, 2007).

Several methodological limitations must be acknowledged. The study relies exclusively on publicly disclosed documents and therefore evaluates communicated governance structures rather than internal managerial processes. Prior research indicates that sustainability disclosures may be influenced by legitimacy considerations or impression management dynamics (Jamali & Mirshak, 2007). Furthermore, the study is limited to Slovenian companies and does not pursue cross-country comparison. However, by using ESRS E5 as an explicit analytical benchmark, the research provides a structured assessment of the degree to which corporate waste management reporting aligns with emerging European sustainability reporting standards (Čufar et al., 2024).

4 Results

4.1 Extent of Waste-Related Disclosures (RQ1)

The qualitative content analysis of annual and sustainability reports of nine Slovenian companies within the initial scope of the CSRD reveals substantial sectoral differences in the extent of waste-related disclosures. The analysed sample includes companies operating in the following sectors: reinsurance (2 companies), banking (2 companies), telecommunications (1 company), pharmaceuticals (1 company), chemicals and industrial production (1 company), energy and fuel distribution (1 company), and logistics (1 company). This sectoral diversity enables cross-case comparison between materially intensive industries and service-oriented financial institutions, thereby allowing assessment of whether the degree of waste-related governance integration is conditioned by sectoral materiality. Reinsurance and banking companies provide limited and predominantly indirect disclosures related to waste management. Reporting is primarily focused on general ESG commitments,

greenhouse gas emissions (Scope 1 and Scope 2), sustainable finance instruments, and governance structures related to climate risk. Quantitative indicators concerning total waste generation, hazardous waste, recycling rates, or waste treatment methods are either absent or presented in a highly aggregated manner. In these cases, waste management does not appear as a material or strategically prioritised reporting category.

In contrast, industrial and logistics companies provide substantially more extensive waste-related disclosures. These organisations report quantitative data on total waste volumes, hazardous and non-hazardous waste, recycling rates, waste recovery processes, and circular economy initiatives. In several cases, waste indicators are systematically structured and aligned with ESRS E5 logic, including differentiation between waste streams and treatment methods. The level of granularity and transparency suggests that waste management represents a materially significant operational issue in these sectors.

Companies operating in telecommunications and pharmaceuticals occupy an intermediate position. They report quantitative waste data and certain environmental initiatives, however, disclosures remain predominantly operational in nature and less integrated into strategic or governance frameworks. While structured data are present, explicit linkage to long-term circular economy objectives or governance-level oversight mechanisms is less pronounced compared to heavy industrial sectors. Overall, the findings indicate that the extent of waste-related disclosures correlates strongly with sectoral materiality. Companies whose core operations generate significant physical outputs and by-products provide more comprehensive reporting, whereas service-oriented financial institutions demonstrate minimal direct waste reporting.

4.2 Level of Governance Integration of Waste Management (RQ2)

Beyond the mere extent of disclosures, the study systematically examined the vertical integration of waste management across political, strategic, and operational levels of governance. This multi-level analysis allows for assessing whether waste-related reporting reflects isolated environmental practices or coherent governance embedding consistent with the logic of integrated sustainability management.

Political Level

At the political level, most companies articulate broad sustainability commitments within their mission statements, value systems, corporate governance codes, or board-level charters. Environmental responsibility is frequently presented as part of organisational identity, ethical conduct, or long-term societal responsibility. ESG principles are often formally embedded within corporate governance structures, including supervisory board oversight, sustainability committees, and updated codes of conduct. However, explicit political level commitment to circular economy principles, resource responsibility, or systematic waste reduction as a defining element of corporate purpose remains limited across the sample. In most cases, environmental stewardship is framed in general terms (such as climate responsibility, sustainable growth, or environmental awareness) without direct reference to material flow management or waste minimisation as foundational corporate values. Industrial and logistics companies demonstrate comparatively stronger embedding when sustainability statements explicitly refer to resource efficiency, circularity, or responsible material use. In these cases, environmental considerations are linked to the organisation's production philosophy and long-term legitimacy within the broader socio-economic system. Waste management is more clearly positioned as part of the company's licence to operate. In contrast, financial institutions exhibit high levels of general ESG institutionalisation, including strong governance frameworks, sustainability committees, and external commitments. Nevertheless, waste management as such is not normatively articulated as a governance priority. Instead, environmental legitimacy is framed primarily through climate risk, green financing, and portfolio decarbonisation, leaving internal resource use and waste practices largely peripheral at the political level. Overall, integration of waste management on the political level remains implicit rather than explicit in most cases, indicating that waste is rarely conceptualised as a core dimension of corporate identity.

Strategic Level

Strategic integration varies considerably across cases and represents the most differentiating governance dimension. Only a minority of companies define explicit long-term waste reduction targets, measurable circular economy objectives, or strategic waste-related KPIs embedded within corporate strategy documents. Where

such targets exist, they are predominantly found in industrial and energy-related companies, where waste generation directly affects production efficiency, regulatory exposure, cost structures, and stakeholder scrutiny. In these sectors, waste management is occasionally translated into measurable objectives (such as increasing recycling rates, reducing hazardous waste intensity, or improving material recovery performance), suggesting alignment between sustainability ambitions and business strategy. However, in the majority of cases, sustainability strategies prioritise decarbonisation, energy transition, climate risk management, and green investment portfolios. Waste management is either subsumed under broader environmental efficiency initiatives or addressed indirectly through operational optimisation. Explicit articulation of circular economy strategy, closed-loop systems, or material productivity frameworks remains rare. This pattern suggests that strategic prioritisation of waste is uneven and strongly conditioned by sectoral materiality. Where waste materially influences operational performance, strategic embedding is more pronounced. Where environmental impact is perceived as indirect or reputational, waste management remains secondary within sustainability strategies. Consequently, while a sustainability strategy is present across nearly all analysed companies, its translation into structured waste-related strategic commitments is limited.

Operational Level

Operational integration is the most consistently observed dimension across the sample. Several companies provide quantitative indicators concerning total waste generation, hazardous and non-hazardous waste, recycling volumes, recovery rates, and disposal methods. In some cases, disclosures are aligned with recognised reporting standards and include year-on-year comparisons. Operational initiatives frequently include:

- Process optimisation aimed at reducing material losses
- Waste separation programmes across facilities
- Internal waste tracking mechanisms
- Investments in recycling infrastructure
- Efficiency improvements in logistics and packaging

These measures demonstrate that waste management is actively addressed at the implementation level, particularly in sectors characterised by physical production and material throughput. However, the presence of operational indicators does not automatically imply governance integration. In numerous cases, operational reporting appears disconnected from explicit strategic objectives or normative commitments. Waste data are presented descriptively, without clear linkage to long-term targets, board oversight, or performance-based accountability mechanisms. This disconnection suggests a form of fragmented sustainability governance, where environmental performance is monitored at the implementation level but not fully embedded within strategic planning or corporate purpose. Operational performance may therefore reflect compliance or efficiency considerations rather than deliberate strategic transformation toward.

4.3 Patterns of Vertical Coherence

When examining the three levels collectively, the analysis reveals that full vertical alignment is relatively rare. Most companies demonstrate strength at one or two levels but lack comprehensive integration across all three. Financial institutions show strong ESG governance at the political level but weak operational waste reporting. Industrial companies show strong operational integration but variable normative articulation. Telecommunications and pharmaceutical firms demonstrate operational reporting without consistent strategic embedding. These findings indicate that waste management, despite being a clearly defined disclosure category under ESRS E5, remains predominantly operational in character. Strategic integration and embedding at the political level depend heavily on sector-specific materiality and regulatory anticipation rather than on uniformly integrated governance logic. The findings demonstrate that vertical coherence across governance levels remains limited across the sample. Full integration is observed only in a small number of materially intensive sectors.

4.4 Implications for ESRS E5 Alignment

When assessed against the disclosure logic of ESRS E5, the majority of analysed companies demonstrate partial alignment, primarily concentrated at the operational disclosure level. Quantitative information on waste volumes, separation rates, or recycling performance is frequently provided, particularly in materially intensive

sectors. However, such disclosures are often not accompanied by clearly articulated waste-specific policies, long-term strategic targets, or explicit board-level oversight mechanisms. As a result, compliance appears procedural rather than structurally embedded within governance architecture. The absence of systematic linkage between operational metrics and higher-level governance structures suggests that waste management is still predominantly conceptualised as an environmental performance category rather than as a strategically governed resource management issue. While companies increasingly adopt ESG frameworks and sustainability strategies, the translation of these commitments into circular economy logic remains uneven and frequently implicit. The findings further indicate that the depth of integration is strongly conditioned by sectoral materiality. Companies operating in heavy industry, logistics, or energy sectors exhibit comparatively stronger alignment with ESRS E5 components. In contrast, service-based and financial institutions, despite demonstrating advanced ESG institutionalisation, provide limited substantive engagement with resource use and waste flows. This pattern suggests that, prior to the full enforcement of the CSRD and mandatory ESRS reporting standards, corporate adaptation has been largely driven by perceived material risk and operational relevance rather than by anticipatory harmonisation with the comprehensive governance logic embedded in ESRS E5. In other words, regulatory transformation toward governance-integrated sustainability has not yet produced uniform structural alignment across sectors. Instead, reporting practices reflect incremental and sector-dependent adjustments, revealing a transitional phase between voluntary ESG-oriented transparency and fully institutionalised, standardised sustainability governance.

5 Discussion

The findings of this study indicate that waste management remains predominantly operational in nature across the analysed companies, even when assessed within the structured disclosure logic of ESRS E5, which requires reporting on policies, actions, targets, resource inflows, and waste outflows. Although several companies provide quantitative data on waste generation, recycling rates, and recovery processes, these disclosures are frequently not embedded within a coherent governance architecture. In most cases, operational indicators are presented without clear strategic targets, explicit commitments on the political level, or systematic board-level oversight. As a result, alignment with ESRS E5 appears partial and uneven, suggesting procedural

adaptation rather than fully institutionalised governance integration. From the perspective of integral management, sustainability requires vertical coherence across political, strategic, and operational levels. Integration on the political level implies that corporate purpose, values, and governance principles explicitly recognise resource responsibility and circular economy logic as part of organisational identity and legitimacy. Strategic integration requires translation of these principles into measurable long-term objectives, investment priorities, and risk management structures. Operational integration involves implementation through processes, metrics, monitoring systems, and performance evaluation. The empirical analysis demonstrates that this vertical alignment is rarely fully realised in the domain of waste management. Instead, companies tend to exhibit strength at one level while remaining underdeveloped at others. Operational reporting is relatively common, strategic articulation is selective and sector-dependent, and embedding of circular economy principles on the political level remains largely implicit. Stakeholder theory helps explain this pattern.

Corporate responsiveness to sustainability issues is influenced by stakeholder salience and perceived materiality. In sectors where waste generation directly affects regulatory compliance, operational efficiency, or reputational exposure (such as heavy industry, logistics, and energy), waste management becomes strategically relevant and more deeply integrated. In contrast, financial institutions, despite demonstrating advanced ESG institutionalisation and strong governance frameworks, rarely treat internal waste management as a strategic priority. Their sustainability focus is directed toward climate risk, green financing, and portfolio decarbonisation, reflecting the expectations of investors, regulators, and capital markets rather than operational resource flows. This divergence illustrates that ESG commitment on the political level does not automatically translate into issue-specific governance integration. Waste becomes strategically embedded primarily when it intersects directly with economic performance, regulatory pressure, or stakeholder scrutiny. The results further suggest that sectoral materiality strongly conditions the degree of ESRS E5 alignment. Industrial and logistics companies display more comprehensive reporting structures, often including differentiated waste streams, recovery mechanisms, and quantitative indicators aligned with circular economy objectives. In these contexts, waste management is closely linked to cost structures, risk exposure, and operational continuity, thereby facilitating deeper governance embedding. By contrast, service-oriented and financial firms exhibit limited direct

engagement with material flows and provide minimal structured reporting on waste, even when their ESG governance frameworks are otherwise robust. This indicates that, prior to full CSRD enforcement, corporate adaptation remains primarily reactive and sector-driven rather than uniformly aligned with the comprehensive governance logic embedded in ESRS. The transition from the NFRD to the CSRD represents a qualitative regulatory shift from transparency-oriented disclosure toward governance-embedded accountability. Under the earlier regime, sustainability reporting often remained descriptive, heterogeneous, and loosely connected to strategic management. The present findings suggest that many companies are still operating within this transitional paradigm. Waste-related disclosures, where present, frequently reflect compliance with environmental management practices rather than integrated strategic positioning. The implications for corporate governance under CSRD are significant. ESRS E5 explicitly requires structured disclosure on resource use and circular economy, thereby institutionalising waste management within the broader sustainability governance architecture. If implemented rigorously, the directive may reduce current sectoral variability and promote more consistent vertical integration. However, the present analysis indicates that, before full regulatory enforcement, corporate responses are shaped more by sector-specific exposure and perceived materiality than by comprehensive anticipatory alignment with the new governance model. Waste management thus serves as a revealing diagnostic indicator of governance maturity. Where vertical coherence exists, sustainability approaches integral management, where it does not, ESG remains partially institutionalised but strategically incomplete. In theoretical terms, the study demonstrates that waste management can function as a lens for assessing the depth of sustainability integration within corporate governance structures. Rather than evaluating environmental performance outcomes alone, the analysis highlights the importance of structural alignment between corporate purpose, strategic intent, and operational execution. The findings reinforce the proposition that sustainability integration cannot be achieved through disclosure mechanisms in isolation. It requires systemic embedding across governance levels.

From the perspective of the renewed MER model of integral management and governance, sustainability governance requires not only vertical coherence between political, strategic, and operational levels, but also process, instrumental, and institutional integration within a consistently functioning whole. The empirical

findings of this study indicate that waste management within the analysed companies rarely achieves such multi-dimensional integration. While operational processes and quantitative indicators are frequently present, they are often not systematically connected to political-level policy formulation or to strategic decision-making structures. Moreover, the instrumental dimension (values, guiding principles, and management styles) seldom explicitly incorporates circular economy logic. In addition, the institutional dimension does not consistently demonstrate clearly assigned governance responsibilities for resource stewardship. Waste management is addressed functionally, but not integrally aligned with enterprise policy, strategic development, and long-term competitiveness. The absence of holistic ecological orientation, understood in the MER model of integral management and governance as a key success factor, therefore, explains why waste disclosures tend to remain administratively compliant rather than constitutive elements of integral governance. Integrating zero-waste management into corporate governance consequently requires systemic alignment across all MER dimensions, ensuring that political commitments guide strategies, strategies structure operational execution, and ecological responsibility becomes embedded within the enterprise's core philosophy, culture, and decision-making structure.

6 Conclusions

This study examined the extent and depth of waste management integration within the corporate governance structures of nine Slovenian companies. Applying a multi-level analytical framework grounded in the MER model of integral management and governance (political, strategic, and operational levels), the research assessed whether waste management is treated as a peripheral environmental reporting issue or structurally embedded within governance architecture in alignment with ESRS E5 requirements. The findings reveal that waste management remains predominantly operational in character, with only limited vertical coherence across political, strategic, and operational levels. While several companies disclose quantitative indicators related to waste generation, recycling rates, and recovery practices, these measures are rarely supported by explicit political-level commitments or systematically translated into long-term strategic objectives. The observed patterns suggest partial governance integration rather than fully coherent integral management. The results further indicate that, prior to full CSRD implementation, corporate adaptation is driven primarily by sectoral materiality rather than by

comprehensive anticipatory alignment with the governance logic embedded in ESRS E5. Waste management continues to be framed largely as an environmental performance and reporting category, rather than as a strategically governed resource management challenge integrated into corporate purpose and long-term value creation. The depth of integration, therefore, depends significantly on operational exposure and regulatory risk, rather than on uniform governance embedding across sectors. From a theoretical perspective, the study contributes by applying a vertical integration lens to assess sustainability governance maturity. The findings indicate that genuine integration requires structural coherence between corporate purpose on the political level, strategic objectives, and operational performance indicators. In the absence of such alignment, sustainability risks remain fragmented, despite increasing regulatory formalisation and expanding disclosure requirements.

Beyond the empirical assessment of reporting practices, the study demonstrates how integrating zero-waste management into corporate governance can be systematically approached through the application of the MER model of integral management and governance. The MER model of integral management and governance provides a structured architecture for evaluating whether environmental initiatives are anchored in corporate political, strategic, and operational levels of management. In this sense, integrating zero-waste management into corporate governance does not merely imply expanding environmental disclosure but requires achieving vertical coherence across governance levels. The application of the MER model of integral management and governance thus offers both an analytical and managerial pathway for transforming waste management from an operational environmental activity into a structurally embedded governance principle consistent with the evolving CSRD and ESRS framework. Future research may adopt a longitudinal perspective following full CSRD enforcement to examine whether regulatory standardisation fosters deeper governance embedding of circular economy principles and strengthens vertical alignment across corporate governance levels.

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A PRACTICE-BASED GOVERNANCE FRAMEWORK FOR MANAGING DIGITAL AND SUSTAINABLE TRANSFORMATION

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The dual transformation towards sustainability and digitalization confronts manufacturing companies with complex and often conflicting governance demands. Although governance is increasingly seen as a key enabler of organizational change, existing approaches rarely address the integrated challenges of simultaneous sustainability and digital transformation. We present a practice-based Dual Governance Framework that supports organizations in strategically embedding and operationalizing dual transformation. Developed through iterative design science research, the framework builds on academic literature, stakeholder input from a multi-partner research consortium, and insights from industry pilot projects. It identifies six governance areas, including integrated business strategy and compliance, and links them to six overarching principles such as stakeholder integration and transparency. To facilitate operationalization, we introduce the Dual Governance Map that enables structured reflection across governance domains and supports context-specific development. The framework provides a coherent and actionable governance architecture that bridges theory and practice and supports dialogue with internal and external stakeholders.

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1 Introduction

Manufacturing firms are confronted with a concurrent acceleration of digital and sustainability transformations. Rapid advances in digital technologies are reshaping products, processes, and value creation logics, while regulatory developments, stakeholder expectations, and societal demands increasingly require companies to embed environmental and social considerations into their core strategies. At the European policy level, initiatives such as Industry 5.0 and the expansion of ESG-related regulation signal that competitiveness, resilience, and sustainability are no longer treated as separate agendas, but as interdependent dimensions of industrial development (Broccardo, Zicari, et al., 2023; EC DG RTD, 2022; Rehman & Umar, 2025). A growing body of literature has emerged to capture this increasing entanglement of technological and sustainability-oriented change processes, conceptualized under multiple terms – such as Twin Transformation, Double Transformation, and Dual Transformation (Epp et al., 2025; Hinsén et al., 2023; Hofmann et al., 2024; Kürpick et al., 2023). While these concepts differ in scope and emphasis, they converge in recognizing that digitalization frequently acts as an enabler of sustainability objectives, and that sustainability considerations increasingly shape the direction of digital innovation (Epp et al., 2025; Hahn et al., 2014).

However, this interdependence does not only generate synergies; it also produces tensions, trade-offs, and coordination challenges. Digital investments may prioritize efficiency, speed, and competitive advantage, while sustainability objectives emphasize long-term resilience, stakeholder inclusion, and environmental responsibility. These potentially competing priorities create conflicts in resource allocation, accountability structures, and performance measurement systems. Managing dual transformation – understood as the strategic integration and mutual interdependence of digitalization and sustainability within firms (Epp et al., 2025; Kürpick et al., 2023) – is therefore not merely a matter of coordinating two parallel change initiatives. Rather, it requires embedding both transformation logics within a coherent governance architecture that structures decision rights, allocates responsibilities, aligns incentives, and ensures accountability across organizational levels (Naciti et al., 2022; OECD, 2023). Existing contributions predominantly focus on technological enablement or strategic alignment, while the institutional and structural implications for corporate governance (CG) remain comparatively underexplored (Epp et al., 2025; Kürpick et al., 2023).

Governance has long been recognized as central to the integration of sustainability into corporate strategy, particularly through mechanisms such as board oversight, transparency, stakeholder engagement, and strategic alignment (Christensen et al., 2014; E-Vahdati et al., 2019). In parallel, research on digital transformation emphasizes that effective transformation depends on governance structures, processes, and relational mechanisms that extend beyond traditional IT control frameworks (Jewer & Van Der Meulen, 2022; Spremic, 2017). Yet these governance discourses have largely evolved along separate trajectories: Sustainability governance frameworks rarely integrate digital decision architectures, while digital governance models rarely embed ecological and social objectives as core steering dimensions (Cordero et al., 2020; Hba & Manouar, 2017). This separation creates a critical void: Dual transformation is increasingly recognized as a strategic necessity in manufacturing contexts (Epp et al., 2025; Kürpick et al., 2023) confronting firms with the need to coordinate interdependent transformation processes and adapt their governance architecture accordingly. At the same time, no integrative governance framework currently provides systematic guidance for developing a coherent governance design capable of aligning strategic intent, operational execution, and stakeholder accountability across both domains. Against this backdrop, this paper addresses the following research question:

How can corporate governance (CG) be tailored to address the specific requirements of managing sustainability and digitalization in manufacturing companies?

To answer this question, we introduce the Dual Governance Framework, developed within the publicly funded research project “DualStrat”. The project was conducted in close collaboration with companies from the manufacturing industry, a sector that is particularly central to sustainability transitions and digital transformation alike. Manufacturing firms combine high environmental impact with complex value chains, capital-intensive production systems, and substantial potential for digital automation and process optimization (Schreiner et al., 2024). Against this background, manufacturing firms can be expected to face strong regulatory and stakeholder pressures, while simultaneously possessing significant technological leverage to shape sustainability outcomes. In this context, the integration of sustainability and digitalization becomes strategically decisive, making manufacturing a particularly insightful setting for the development and testing of integrative governance approaches. Building on a conceptual Reference Model of

Dual Transformation (Epp et al., 2024), a systematic literature review (SLR) (Epp et al., 2025), and empirical insights (Kürpick et al., 2024), the framework specifies six governance areas and six overarching principles that jointly operationalize governance for dual transformation. Complementary instruments – including the Dual Governance Map and an extended RAECI matrix – support practical implementation and responsibility alignment. By systematically integrating sustainability and digitalization into a coherent governance framework, this paper contributes both conceptual clarification and actionable guidance for manufacturing firms navigating dual transformation.

2 Background

2.1 Dual Transformation

The parallel acceleration of digitalization and sustainability imperatives has generated new types of strategic and organizational challenges in contemporary manufacturing. Digital technologies enable real-time data processing, process automation, predictive analytics, and the development of new data-driven business models, thereby reshaping operational performance and value creation logics (Baskerville et al., 2020). At the same time, sustainability has evolved from a predominantly regulatory or compliance-driven concern into a strategic imperative that directly influences innovation trajectories, organizational design, and CG structures (Christmann et al., 2024; Epp et al., 2025; Hahn et al., 2014).

Despite their strategic relevance, both transformation logics are frequently pursued in isolation, resulting in fragmented strategies, misaligned priorities, and unrealized synergies (Barth et al., 2023; Broccardo, Truant, et al., 2023; Santarius et al., 2023). This fragmentation can manifest in digital investments that are weakly aligned with sustainability goals, or in sustainability initiatives that lack scalability due to insufficient governance integration (Flyverbom et al., 2019). In response, a growing body of literature has introduced different concepts to capture the increasing interdependence between digitalization and sustainability. Research distinguishes between two complementary directions of dual transformation: (1) sustainable digitalization, where digital technologies enable sustainability outcomes (e.g., data-driven circularity, platform-based energy optimization), and (2) digital sustainability, where digital transformation itself is governed by ecological and social standards.

While mutually reinforcing, these directions also generate tensions, trade-offs, and coordination demands that challenge linear or siloed approaches to strategic management (Epp et al., 2025; Hahn et al., 2014; Scherer et al., 2018).

To address their interrelation more explicitly, broader umbrella terms such as Twin Transformation and Double Transformation have emerged. Twin Transformation typically refers to the parallel and coordinated advancement of digital and sustainability transformations to leverage synergies and increase efficiency (Hinsen et al., 2023). Double Transformation is framed at a systemic level, highlighting digitalization as an enabler of a comprehensive socio-economic realignment toward sustainability goals (Hofmann et al., 2024). Building on this evolving discourse, we use the term Dual Transformation (Epp et al., 2025; Kürpick et al., 2023) to emphasize the strategic integration and mutual interdependence of digitalization and sustainability within firms. Rather than treating them as parallel change processes, Dual Transformation conceptualizes both dimensions as reciprocally reinforcing and governance-relevant transformation logics that must be deliberately aligned at the strategic and organizational level.

2.2 Towards Dual Governance

As informational flows intensify and digital infrastructures permeate economic and societal systems, governance processes themselves are reshaped. Governance is no longer solely based on hierarchical control and authoritative resources, but increasingly structured through data flows, interconnected actors, and digitally enabled coordination (Soma et al., 2016; Varoglu et al., 2021). This development is particularly relevant in sustainability contexts, where environmental challenges such as climate change or resource depletion require complex, multi-actor governance arrangements under conditions of uncertainty and time lags (Soma et al., 2016; Underdal, 2010). However, existing governance approaches often struggle to adequately address these evolving coordination demands, which makes it necessary to critically revisit dominant CG paradigms and their underlying assumptions. Despite its widespread use, CG is not defined uniformly; instead, it reflects a plurality of theoretical traditions that differ in their conceptualization of accountability, control, and organizational purpose.

In its classical understanding – particularly prevalent in the Anglo-American context – CG is rooted in agency theory, conceptualizing the relationship between owners (principals) and managers (agents) as one of potential conflict and information asymmetry (Jensen & Meckling, 1976). Hence, governance seeks to ensure that managers act in the interest of shareholders and maximize profit, often through control mechanisms, incentives, and monitoring systems (Shleifer & Vishny, 1997). This perspective has shaped both academic theory and policy frameworks for decades, emphasizing compliance, fiduciary responsibility, and board effectiveness (Naciti et al., 2022; OECD, 2023). Over time, this shareholder-centric perspective has been expanded and complemented by alternative theoretical perspectives. Stakeholder theory reconceptualizes governance as a mechanism for balancing heterogeneous interests and enhancing organizational legitimacy (Freeman, 1984). Stewardship theory challenges assumptions of opportunistic behavior by portraying executives as intrinsically motivated stewards pursuing long-term organizational goals (Donaldson & Davis, 1991). Social contract theory embeds governance within a broader societal context, framing organizational legitimacy as derived from implicit public expectations (Donaldson & Dunfee, 1999). Strategic governance perspectives further extend this view by positioning governance as a source of competitive advantage (Porter & Kramer, 2006), contributing to resilience, credibility, and adaptability in dynamic environments (Lanfermann, 2023).

Across these perspectives, governance is increasingly understood not merely as a legal or institutional arrangement, but as a normative and strategic architecture (Manning & Reinecke, 2016) that structures decision-making, allocates responsibilities, and enables coordination across organizational boundaries. Core governance functions include defining roles and accountabilities, shaping incentive systems, embedding stakeholder integration, safeguarding integrity and compliance, and managing complexity and risk (E-Vahdati et al., 2019; Manning & Reinecke, 2016; OECD, 2023). This broadened understanding of governance has been further institutionalized through the rise of Environmental, Social, and Governance (ESG) frameworks. Emerging in the early 2000s through a United Nations led initiative, ESG criteria have become central reference points for responsible investment, regulatory development, and the assessment of corporate conduct (UN Global Compact, 2004; UNEP, 2005). ESG frameworks formalize expectations regarding how organizations integrate environmental and social considerations into strategic

decision-making and operational practices, while explicitly positioning governance as the enabling dimension that translates normative goals into organizational action.

Within ESG, the “G” dimension has gained renewed prominence. Rather than being limited to formal compliance or reporting structures, governance is increasingly defined in comprehensive terms. As part of the EU’s sustainable finance framework, ESRS-G1 (“Business Conduct”) encompasses corporate culture, anti-corruption measures, supplier relationships, political engagement, payment practices, and grievance mechanisms (Lanfermann, 2023). Recent literature highlights that such regulatory standards are increasingly shaping internal governance design, not just in response to legal demands but also as a strategic instrument to meet stakeholder expectations and support systemic transformation (E-Vahdati et al., 2019; Naciti et al., 2022). Governance is thus framed as a driver of ethical behavior, strategic coherence, and long-term value creation, extending well beyond traditional board-level oversight.

Parallel to this institutional development, academic research on governance for sustainability has emphasized the need to embed ecological and social considerations directly into governance systems. Concepts such as the triple bottom line (Elkington, 2006) and green governance (Debbarma & Choi, 2022) call for integrative governance models that reconcile economic performance with environmental stewardship and social responsibility. At the same time, digitalization has introduced new governance challenges. While IT governance frameworks such as COBIT, ISO/IEC 38500, TOGAF, and ITIL 4 provide detailed guidance for steering information systems, they often remain disconnected from broader sustainability strategies (Cordero et al., 2020). Governance mechanisms for digital transformation (DT), as highlighted by Jewer & Van Der Meulen (2022), must extend beyond IT-specific structures to address cross-functional synergies, dynamic environments, and organization-wide strategic alignment. They argue that traditional IT governance logics – overly hierarchical, functionally siloed, and focused on compliance – do not suffice for DT, which demands horizontal coordination, real-time adaptability, and cultural transformation.

The separation of governance logics between sustainability and digital transformation has created strategic and practical blind spots. Sustainability governance research emphasizes normative orientation, stakeholder integration,

leadership commitment, and transparency, while digital governance research focuses on technological coordination, structural agility, and cross-functional integration. Both streams offer valuable insights, yet they remain insufficiently integrated. For manufacturing firms undergoing dual transformation, this separation is increasingly challenging. Digital infrastructures shape sustainability performance through data transparency, traceability, and process optimization, while sustainability objectives influence digital investment priorities, innovation pathways, and risk governance. Governance must therefore reconcile technological decision architectures with environmental and social accountability structures.

Existing frameworks address these challenges only partially and in isolation. IT governance frameworks such as COBIT provide structured guidance for digital steering and control, yet remain largely disconnected from sustainability strategies (Cordero et al., 2020; De Haes et al., 2020; Hba & Manouar, 2017). Sustainability governance research emphasizes normative orientation, stakeholder integration, and board-level accountability, but does not systematically incorporate digital decision architectures (E-Vahdati et al., 2019; Naciti et al., 2022). Studies at the intersection of both domains point toward the need for integration (Jewer & Van Der Meulen, 2022; Manning & Reinecke, 2016; Soma et al., 2016), but do not currently provide an operationalizable framework tailored to the requirements of dual transformation.

Addressing these challenges requires a governance logic that bridges normative orientation and operational control, stakeholder engagement, and digital enablement. Governance must therefore be conceptualized as a dynamic coordination and control system capable of reconciling competing objectives, managing trade-offs, and supporting organizational learning across domains. In response, we introduce the concept of Dual Governance as an integrative governance architecture that jointly addresses sustainability and digitalization. Dual Governance extends foundational CG principles to support multidimensional value creation through adaptive structures, clearly defined roles and responsibilities, and digitally supported transparency and accountability mechanisms. By embedding sustainability considerations into digital decision-making – and vice versa – Dual Governance provides a conceptual foundation for overcoming fragmentation and strategically steering dual transformation in manufacturing organizations.

3 Method

The Dual Governance Framework presented in this paper emerged from a design-oriented and iterative development process that deliberately integrates conceptual reasoning with practical requirements. Rather than following a linear development logic or relying on a single empirical study, the framework evolved through successive cycles of reflection, conceptual refinement, and tool development, continuously informed by dialogue with academic peers and practitioners from manufacturing companies. Methodologically, this approach is grounded in Design Science Research (Gregor & Hevner, 2013; Hevner et al., 2004; March & Smith, 1995), which emphasizes the intertwined pursuit of relevance and rigor through iterative design, evaluation, and refinement in response to real-world problem contexts. The research architecture that informed the Dual Governance Framework is built in three layers (see Fig. 1): (1) A knowledge base, formed by an SLR (Epp et al., 2025) and supplemented with exploratory interview insights (Kürpick et al., 2024); (2) The conceptual Reference Model (Epp et al., 2024); (3) and the Dual Governance Framework as a guideline for organizations to embed and strategically operationalize dual transformation.

The Knowledge Base is grounded in an SLR (Epp et al., 2025) that consolidates scholarly work situated at the intersection of digitalization and sustainability within the field of strategic management. The SLR ($n = 74$) underscores both the pressing relevance of this research area and the fragmented nature of existing debates, revealing a notable absence of integrative and practically applicable frameworks that address dual transformation in a comprehensive and strategic manner. While a substantial body of literature recognizes digitalization and sustainability as key forces shaping organizational change, only a limited number of studies explicitly examine their interaction or offer structured guidance for their joint incorporation into corporate strategy. To complement the insights derived from the literature, qualitative interviews with practitioners ($n = 11$) were conducted to obtain practice-oriented perspectives on capability requirements, enabling factors for change, and organizational tensions inherent in transformation processes (Kürpick et al., 2024). The purpose of these interviews was to support the conceptualization of a maturity model for dual transformation. In doing so, they contribute to identifying gaps in prevailing strategic models and to refining the operational understanding of dual

transformation as a challenge rooted in both capabilities and processes (Kürpick et al., 2024).

The Reference Model for Dual Transformation (Epp et al., 2024) delineates the strategic rationale underlying dual transformation by building a shared understanding of what dual transformation contains and integrating perspectives from strategic management, transformation theory, sustainability science, and digitalization research. Accordingly, the model provides the conceptual foundation of the Dual Governance Framework by embedding strategic choices within a holistic, multidimensional view of transformation demands while delineating the substance of the dual transformation itself. The model thus serves as a starting point for analyzing the concrete mechanisms required to purposefully structure and effectively steer dual transformation. Consequently, the model is – both conceptually and visually – incorporated into the framework's background (Fig. 1 and 3).

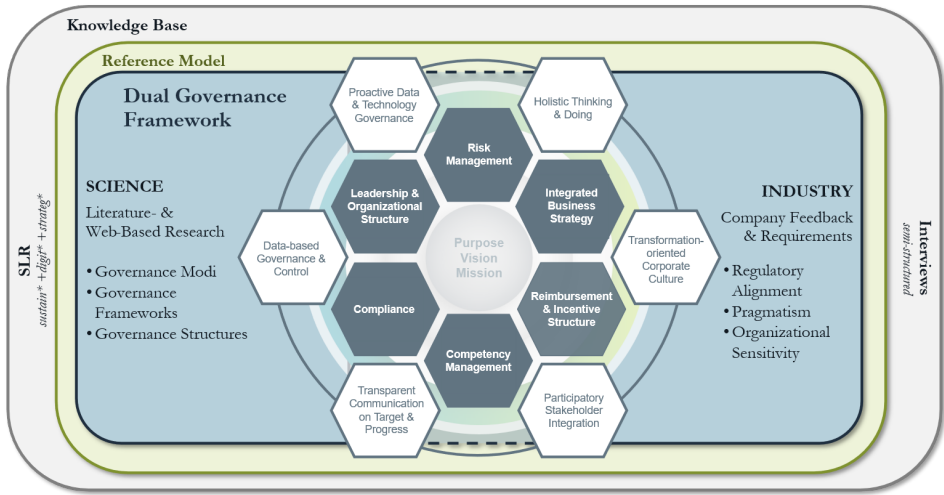


Figure 1: Research Strategy
Source: own.

The Dual Governance Framework draws on the above outlined research and supports organizations in strategically embedding and operationalizing dual transformation. Its design logic was shaped by two complementary strands: theoretical-conceptual inspirations on the one hand, and normative-practical requirements from industrial application on the other (Fig. 1). On the conceptual

side, the framework builds on the Organisation for Economic Co-operation and Development (OECD) Principles on CG, which include key aspects such as quality of data, sustainability, risk management, and resilience (OECD, 2023). We furthermore included established governance frameworks such as COBIT (De Haes et al., 2020; Mangalaraj et al., 2014), as well as on the principles of design science research (Hevner et al., 2004; March & Smith, 1995). On the normative-practical side, the framework was iteratively refined through structured stakeholder input from the multi-partner research consortium. The aforementioned models contributed important impulses, including modular structuring, lifecycle orientation, and clearly defined roles and responsibilities. However, none of them sufficiently capture the complexity, interdependence, and dynamic openness that characterize dual transformation processes in real-world organizational settings.

To address this gap, the project team initiated an iterative design process (Fig. 2) aiming to adapt and extend the latest COBIT framework in alignment with the OECD principles and preliminary conceptual work on dual transformation. The development followed a cycle of consortium workshops and industry feedback loops, through which successive interim versions of the framework were conceptually refined and continuously adjusted considering practical input. Within the research consortium, scholarly perspectives from IT governance, circularity, and transformation research were integrated to shape the conceptual architecture of the framework. Ongoing exchange with industry partners ensured that theoretical coherence and practical applicability evolved in parallel. In particular, the primary industry partner, a globally active medium-sized enterprise in the field of industrial engineering, played a significant role in co-shaping the framework. Through regular feedback loops, the company articulated specific expectations that influenced the model's development. These included a clear demand for regulatory compatibility, especially considering the European Sustainability Reporting Standards (ESRS); a pragmatic, low-barrier design with a high degree of agility and proximity to practice; and a holistic perspective that considers not only structures and processes, but also people, culture, and informal power dynamics.

Research Consortium

- **Fraunhofer IEM:** Systems Engineering, Industry 4.0, digital transformation in manufacturing
- **Wuppertal Institute:** Sustainability transitions, circular economy, systemic innovation
- **Heinz Nixdorf Institute:** Behavioral Economic Engineering and Responsible Management
- **InnoZent OWL:** Innovation network supporting SMEs in digitalization, sustainability, and collaborative R&D across industrial sectors

Industry Partners

- **Weidmüller:** Supplier of industrial connectivity and automation solutions (primary industry partner)
- **Schmitz Cargobull:** Leading manufacturer of trailers and transport solutions
- **Böllhoff:** International specialist in fastening and assembly technology
- **Hanning Elektro-Werke:** Manufacturer of customized electric drives



Figure 2: Research Process

Source: own.

Throughout this development process, theoretical insights and practical considerations were not treated as separate inputs but were continuously interwoven. Ultimately, the Dual Governance Framework is a product of methodological pluralism, iterative design, and embedded co-reflection. It serves not just as a coherent and actionable governance framework with its related tools such as the Dual Governance Map but also as a bridge between theory and practice for aligning decision-making structures, responsibilities, and cultural practices with the demands of dual transformation.

4 Results

In the following, the core outcomes of the design process are presented: the Dual Governance Framework as a general governance foundation for sustainability and digitalization transformation, along with the profiles of the 12 elements, and the Dual Governance Map as an instrument for operationalizing the intersections of dual transformation. Additionally, we developed an extended RACI-matrix that enables the definition of and reflection on governance roles.

4.1 The Dual Governance Framework



Figure 3: Dual Governance Framework
Source: own.

The Dual Governance Framework (see Fig. 3) builds on the conceptual foundations laid by the Reference Model for Dual Transformation (Epp et al., 2024), operationalizing its strategic intent into concrete governance architecture. It reframes governance not as a compliance tool but as a strategic coordination system that integrates sustainability and digitalization as mutually reinforcing transformation logics. Rather than managing both agendas separately, the framework facilitates their convergence through aligned responsibilities, structures, and capabilities. Its architecture follows a dual-layered logic: at the core, six interrelated Governance Areas define key structural domains for organizational steering. These are surrounded by six Overarching Principles, which guide the implementation and contextual adaptation of each area. The circular form of the model illustrates the dynamic interplay between content (what needs to be governed) and principle-based process design (how governance should be enacted). Importantly, the framework is not intended as a prescriptive blueprint. Instead, it provides a modular and adaptable orientation that supports self-assessment, prioritization, and iterative development of governance structures in line with dual transformation requirements. The central positioning of Purpose, Vision, and Mission reflects the framework's normative foundation, while its design logic fosters both strategic coherence and practical applicability across diverse organizational contexts.

The Dual Governance Framework comprises six interrelated Governance Areas that jointly structure the strategic implementation of sustainability and digitalization. **(1) Risk Management** embeds systematic processes that explicitly incorporate sustainability- and digitalization-related risks, including reputational, climate-related, and technological risks, thereby using dual transformation as a lever to enhance organizational resilience through early detection, clear escalation pathways, and adaptive response mechanisms. **(2) Integrated Business Strategy** structurally anchors sustainability and digital transformation within the corporate mission, strategic objectives, and action plans, while governance ensures coherence across organizational levels by aligning these elements with overarching steering and control concepts and avoiding fragmentation or short-term optimization. **(3) Reimbursement & Incentive Structures** align monetary and non-monetary incentives with long-term sustainability and digitalization goals, for example through ESG-linked targets or variable compensation components, with governance safeguarding their effectiveness, consistency, and fairness, including at executive and top-management levels. **(4) Competency Management** focuses on the systematic

development of sustainability and digital competencies within a proactive learning culture, defining role-specific qualification requirements, supporting continuous learning across individual, team, and organizational levels, and institutionalizing adaptability and change capability as core competencies. **(5) Compliance** ensures adherence to legal, ethical, and strategic standards through clear responsibilities, transparency, and effective control mechanisms that mitigate risks such as greenwashing or bluewashing. Finally, **(6) Leadership & Organizational Structure** establish clear accountability, roles, and decision-making processes, embedding sustainability and digitalization at board level and integrating them across functional and divisional boundaries to translate strategic intent into coordinated organizational action.

These Governance Areas are guided by six Overarching Principles that shape their implementation and ensure practical applicability in line with the requirements articulated by our industry partners as well as strategic coherence. **(1) Holistic Thinking & Doing** promote cross-functional and cross-level integration, overcoming siloed structures through systemic alignment of strategy, structure, and culture. A **(2) Transformation-oriented Corporate Culture** fosters openness, learning, and iterative development, enabling organizations to experiment with and refine novel approaches. **(3) Participatory Stakeholder Integration** ensures early and continuous involvement of relevant internal and external stakeholders, enhancing legitimacy and leveraging collective intelligence. **(4) Transparent Communication on Target & Progress** supports credibility and trust by making governance objectives and outcomes comprehensible beyond formal disclosure requirements. **(5) Data-based Governance & Control** ground decision-making in reliable data, clear responsibilities, and traceable control mechanisms to support sustainable value creation. Finally, **(6) Proactive Data & Technology Governance** ensures data quality, responsible technology use, and secure, scalable digital infrastructures as key enablers of dual transformation.

Complementing the framework, each governance area as well as the overarching principles are described through a dedicated profile, totaling 12 profiles tailored to the German industrial context¹. These profiles provide both concise summaries and in-depth information, including key tasks and enablers, typical challenges, references

¹ This can be found in the online appendix on pages 7 to 30.

to further sources as well as practical impulses derived from real-world implementation examples. Taken together, the Dual Governance Framework delineates how organizations can systematically govern the interdependencies between sustainability and digitalization, translating strategic intent into resilient structures, capabilities, and decision-making processes.

4.2 The Dual Governance Map & Roles

To facilitate the practical implementation of the Dual Governance Framework, we developed the Dual Governance Map and an adapted RAECI-Matrix as complementary tools that support strategic reflection and organizational learning. The map visualizes the interaction between the framework's six Governance Areas (columns) and its six Overarching Principles (rows) in the form of a 6×6 matrix (see Fig. 4). Each of the 36 fields represents a specific intersection where structural steering domains and normative principles converge – providing a space to reflect on how sustainability and digitalization are governed in practice. It serves as an orientation and dialogue tool: It supports organizations in examining their current governance architecture, identifying blind spots or tensions, and initiating structured conversations about development needs. For each cell, we formulated key questions translating abstract governance principles into concrete organizational routines, decision-making processes, and learning mechanisms. These questions were developed iteratively, informed by conceptual literature, expert input, and empirical insights from the project context.

In addition, exemplary implementation practices at each intersection are illustrated in a subsequent governance map², to increase accessibility and support application in workshops and strategy processes. These examples do not prescribe specific solutions but instead offer inspiration for translating governance design into everyday organizational practice. In combination, the guiding questions and practical examples enable users to systematically reflect on their current state, define target states, and derive action-oriented development steps – either within individual governance areas or across the broader transformation strategy. The maps' modular structure allows for flexible use: Organizations can focus on selected intersections, zoom into priority areas, or engage in cross-functional dialogue around the full

² This can be found in the online appendix on page 33.

matrix. Ultimately, the Map serves to activate the Dual Governance Framework as a living instrument – supporting continuous learning, strategic alignment, and context-sensitive adaptation.

	Integrated Business Strategy	Reimbursement & Incentive Structure	Competency Management	Compliance	Risk Management	Leadership & Organizational Structure
Holistic Thinking & Doing	How is holism in the strategy process guaranteed?	Are incentives systematically aligned?	Does the competence system encourage integrative thinking?	Are normative requirements holistically integrated?	How can risks be considered holistically (e.g., ESG-risks)?	Which structures promote cross-system integration?
Transformation-oriented Corporate Culture	How is transformation translated into strategic guidelines?	Do incentive systems promote a willingness to learn and change?	How is change competence systematically developed and fostered?	Is a values-oriented attitude promoted within the organization?	Does a culture of openly dealing with risks exist?	Which cultural elements promote change and willingness to learn?
Participatory Stakeholder Integration	Are strategic decisions made participatorily?	Do incentive systems consider different stakeholder interests?	Are stakeholder perspectives integrated into learning processes?	How are stakeholders accounted for in compliance management?	How are stakeholders included in risk assessments?	How are internal and external stakeholders systematically involved?
Transparent Communication On Target & Progress	Is progress regarding the strategy implementation being openly communicated?	How are goals, progress and results feedbacked?	Are there transparent competency and development goals?	How is information provided about standards, rules, and their compliance?	How is risk development being communicated?	How transparent are roles, decision-making channels, responsibilities?
Data-based Governance & Control	How is the impact systematically measured and reported back?	Which KPIs measure impact and fairness of the incentive systems?	Is the competence building supported by data?	How is compliance monitoring governed on a data basis?	Is there an integrated, responsible risk controlling?	Are there clear roles of monitoring and assumption of responsibility?
Proactive Data & Technology Governance	How are technologies for strategy implementation used?	Are technological systems used for fairness control?	How are digital tools used in competency development?	Which technical tools support compliance?	Which technologies enable early risk detection?	Which IT and data architecture safeguard governance and accountability?

Figure 4: Dual Governance Map

Source: own.

In addition to the Map, an adapted RAECI matrix³ is used to define and reflect Dual Governance roles. RACI matrices are a common tool to plan, organize and coordinate work by assigning roles and responsibilities to decisions and actions, and are often adapted by adding more than the basic four letters respectively responsibilities to fit the need of the organization (Cabanillas et al., 2012; Smith & Erwin, 2005). The RAECI matrix is a structured role and governance analysis tool that assigns responsibilities for key tasks or decision-making areas across five categories: Responsible, Accountable, Evaluate, Consulted, and Informed. By visualizing role allocations across governance areas and organizational functions, the matrix provides a clear overview of who leads, decides, supports, advises, or needs to be kept informed. When completed collaboratively – ideally within a moderated dialogue – it helps to identify overlapping responsibilities, governance gaps, and missing escalation paths. The tool supports both internal self-assessment and the systematic clarification of roles and decision rights. Furthermore, it enables a transparent comparison between current and target governance states, thereby contributing to sustainable governance transparency and improved coordination in transformation processes. Together, these tools provide a structured yet flexible foundation for reflecting on, shaping, and further developing governance arrangements that support the integrated transformation towards sustainability and digitalization.

5 Discussion

5.1 Theoretical & Practical Contribution

This paper contributes to the literature on CG, sustainability, and digital transformation by advancing the concept of Dual Governance as an integrative governance logic for managing the interdependence between sustainability and digitalization. While prior research acknowledges dual transformation as a critical challenge for manufacturing firms, existing governance approaches – including IT governance frameworks, sustainability governance research, and cross-domain studies at their intersection – address only partial aspects of this challenge and remain fragmented across disciplinary silos (see Section 2.2). By synthesizing insights from CG theory, sustainability governance, digital governance, and ambidexterity-

³ This can be found in the online appendix on pages 34 to 35.

oriented transformation research, this study extends existing work in three ways: First, it conceptualizes governance not merely as a control or compliance mechanism, but as a strategic and normative architecture enabling multidimensional value creation under conditions of complexity and change. Second, it operationalizes dual transformation through six coherent governance areas and six overarching principles, thereby translating abstract transformation logics into a structured governance framework. Third, it systematically integrates sustainability-oriented governance and digital governance perspectives into a unified corporate governance design, thereby addressing the structural separation of these domains in existing research. In doing so, the paper provides a theoretically grounded yet flexible framework that advances the understanding of how CG can be adapted to support transformation processes in line with Industry 5.0.

From a practical perspective, this study offers manufacturing firms concrete guidance for governing sustainability and digitalization in an integrated and strategic manner. The Dual Governance Framework serves as a practice-oriented tool that helps organizations move beyond parallel or siloed initiatives by structuring responsibilities, decision-making processes, incentives, competencies, and compliance mechanisms around dual transformation objectives. Complementing the framework, dedicated governance profiles for each governance area and overarching principle provide concise, role- and domain-specific guidance by outlining key tasks, enabling conditions, typical challenges, and practical impulses derived from real-world implementation examples. The accompanying Dual Governance Map further enhances applicability by translating the framework into a matrix of guiding questions that support reflection, diagnosis, and implementation across organizational levels. Together with the extended RAECI logic, the proposed tools enable firms to clarify accountabilities, align strategic goals with operational execution, and systematically address tensions and trade-offs between sustainability and digitalization.

Through the iterative design process resulting in a framework based on literature and practitioner feedback, this paper provides actionable instruments that support managers, governance bodies, and transformation leaders in designing resilient, transparent, and future-oriented governance structures. Recognizing that the framework's comprehensiveness may initially appear demanding, particularly for organizations with limited governance experience, its modular architecture is

intentionally designed to lower barriers to entry. Organizations are not required to engage with all governance areas or matrix intersections simultaneously; instead, the Map supports selective prioritization, enabling context-sensitive starting points and incremental development. This modularity is intended as a structural response to implementation complexity, not merely a design feature.

5.2 Limitations & Future Research

Although the model provides a structured approach to governing dual transformation, its comprehensiveness, while theoretically desirable, may pose practical challenges particularly for organizations with limited governance maturity or resource constraints. The framework seeks to address this tension through its modular architecture and the flexible entry points provided by the Dual Governance Map, though whether these design features are sufficient under real-world capacity constraints remains an open empirical question, particularly given the breadth of the framework's architecture. Also, it has not yet been subjected to systematic large-scale empirical validation and practitioner input has so far been limited to the context of the DualStrat project. Consequently, the explanatory power and robustness of the framework across heterogeneous organizational contexts remain to be further examined. Further, the study predominantly addresses manufacturing firms, which constrains the immediate generalizability of the findings to other industries. Moreover, the Framework is informed by the experiences of the researchers and practice partners embedded in the German institutional and regulatory environment. This context-specific grounding may shape underlying assumptions about governance structures, stakeholder expectations, and compliance regimes.

Future research should therefore pursue broader empirical testing across sectors, organizational sizes, and governance structures to assess the model's generalizability. Application in other countries could yield further understanding of the scope of its transferability to non-German contexts. In particular, cross-industry and cross-country comparative studies could help identify boundary conditions, contextual contingencies, and necessary adaptations of the framework while further work on modular implementations, and more granular tool-level specifications would enhance its practical applicability. Additionally, longitudinal studies may provide insights into how Dual Governance architectures evolve over time and how they affect organizational performance and transformation outcomes. Future research

may also explore the micro-level behavioral implications of Dual Governance, such as how decision-makers navigate competing logics, how incentive systems influence strategic prioritization, and how digital infrastructures reshape accountability relationships.

6 Conclusion

This study argues that dual transformation is not merely an additive challenge for existing governance systems but represents a structural shift in how organizations must coordinate sustainability and digitalization. By introducing Dual Governance as an integrative governance architecture, the paper provides a conceptual and practical response to this shift. Rather than treating governance primarily as a compliance-oriented function, Dual Governance conceptualizes it as a strategic design lever for aligning regulatory requirements, digital capabilities, and sustainability objectives within a coherent decision architecture. In this sense, governance becomes the central mechanism through which firms translate external pressure – such as ESG regulation and stakeholder demands – into coordinated strategic action. Beyond its conceptual contribution, the paper provides a practice-oriented framework supported by complementary tools that translate dual transformation into actionable governance structures. By bridging theory and practice, the study offers both scholarly insight and practical guidance for organizations seeking to govern sustainability and digitalization in an integrated and future-oriented manner.

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FROM COMPLIANCE TO COMMITMENT: THE ROLE OF CULTURE IN EMBEDDING ESG INTO CORPORATE GOVERNANCE

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The integration of Environmental, Social, and Governance (ESG) principles into corporate governance has become a central element of contemporary management and regulatory discourse. While formal ESG compliance has expanded rapidly in response to regulatory pressure and stakeholder expectations, the depth and effectiveness of ESG implementation vary significantly across organizations and institutional contexts. This paper argues that culture plays a critical mediating role in shaping whether ESG adoption remains a compliance-driven exercise or evolves into a genuine organizational commitment embedded in governance structures and strategic decision-making. Drawing on insights from institutional theory, organizational culture, and cross-cultural management, the paper develops a theoretical framework that explains how national and organizational cultural characteristics influence the internalization of ESG values. The analysis highlights how dimensions such as trust, long-term orientation, power distance, and uncertainty avoidance affect managerial attitudes, governance practices, and the legitimacy of ESG initiatives. The paper contributes to the literature by conceptualizing the transition from compliance to commitment as a culturally contingent process and by identifying the conditions under which ESG becomes a substantive driver of sustainable corporate governance rather than a symbolic or procedural requirement.

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1 ESG and the Evolution of Corporate Governance

Environmental, Social, and Governance (ESG) principles have emerged as a dominant framework for assessing corporate sustainability and responsible business conduct. Initially driven by socially responsible investment and voluntary corporate initiatives, ESG has increasingly become institutionalized through regulation, reporting standards, and stakeholder pressure. As a result, ESG is now closely intertwined with corporate governance, influencing board responsibilities, risk management, performance measurement, and corporate accountability.

Corporate governance traditionally focuses on aligning managerial behaviour with shareholder interests, ensuring transparency, accountability, and effective control mechanisms. The incorporation of ESG extends this perspective by emphasizing broader stakeholder interests, long-term value creation, and societal impact. This shift reflects a transition from a shareholder-centric to a stakeholder-oriented model of governance, in which firms are expected to consider environmental sustainability, social responsibility, and ethical conduct as integral to their strategic objectives. (Paola et al., 2025)

Environmental, Social, and Governance (ESG) principles are increasingly becoming central to corporate reporting and responsible business conduct (Hoang, 2018). ESG is widely regarded as a framework for assessing sustainability, providing firms with structured guidance for reducing their environmental footprint, promoting social responsibility, and improving governance practices (Capatina & Busmachiu, 2024).

However, the formal adoption of ESG regulations does not necessarily translate into substantive changes in organizational behaviour. In many cases, ESG sustainability is not organically embedded within corporate activities or societal norms, but rather remains confined to compliance-oriented practices focused on meeting reporting requirements, mitigating reputational risks, and satisfying external expectations. The way in which ESG practices are implemented and disclosed varies significantly across countries, as they are strongly influenced by the local context, particularly cultural factors (Daugaard & Ding, 2022).

The present study contributes to the existing literature by advancing a conceptual distinction between the symbolic adoption of ESG principles – primarily as a mechanism for achieving legitimacy (compliance) – and their substantive adoption, where ESG values are genuinely integrated into corporate governance and managerial decision-making processes (commitment). Furthermore, based on a conceptual synthesis as a methodological approach, the paper proposes a model linking firms' propensity toward compliance or commitment with the role of national culture and key dimensions of corporate governance. A key limitation of the study lies in its conceptual nature and the absence of empirical validation.

2 From Compliance to Commitment: A Conceptual Distinction

The practical application of the ESG sustainability concept can be understood as the systematic compliance of corporations with a set of regulatory requirements (laws, regulations, standards, and voluntary frameworks) governing environmental protection, social responsibility, and corporate governance practices. This represents, to a large extent, the explicit and formal dimension of corporate sustainability, whose primary objective is to ensure that organizational behaviour aligns with externally defined requirements and internally adopted ESG-related policies. At the same time, ESG sustainability may also be implicitly and strategically embedded in the creation of long-term corporate value, being embraced as a desired trajectory for future development, whereas ESG compliance is more narrowly associated with conformity, monitoring, reporting, and risk mitigation within the established legal and normative environment.

ESG compliance extends corporate reporting requirements beyond financial performance. Traditionally focused on finance, anti-corruption, labour, and competition law, it now encompasses disclosures related to climate impacts, human rights due diligence, inclusive representation of diverse social groups, supply chain transparency, and governance oversight. As such, it has evolved into a multidimensional managerial function, spanning legal, ethical, operational, and reputational domains.

ESG regulations cover environmental standards (including harmful emissions, greenhouse gas emissions, waste management, and climate impact reporting), social responsibility (labour rights, occupational health and safety, and anti-discrimination

protections), and governance rules (board independence, executive compensation, anti-bribery measures, and the effectiveness of internal control systems). Companies are required not only to implement these standards but also to report their ESG performance within relatively standardized frameworks.

ESG compliance is closely linked to corporate risk management, as regulatory violations may result in legal sanctions, financial losses, reputational damage, and diminished investor trust. Firms mitigate these risks by establishing effective internal controls, monitoring systems, dedicated ESG compliance roles, whistleblowing mechanisms, and audit procedures. In this sense, ESG compliance can be primarily conceptualized as a protective governance mechanism (Pollman, 2019).

In the context of ESG compliance, the existence of formalized procedures and measurable indicators is essential, while materiality assessments, documented policies, and external assurance enhance credibility. However, compliance does not guarantee substantive sustainability; adherence to minimum standards may coexist with ethically questionable practices, thereby increasing the risk of greenwashing (Fang et al., 2025). While ESG compliance is undoubtedly necessary to ensure adherence to standards and maintain public trust, it is not sufficient for meaningful sustainability integration. In compliance-driven settings, ESG metrics may function more as instruments of legitimacy than as indicators of genuine strategic commitment. Without strategic alignment, ESG compliance risks becoming a bureaucratic exercise focused primarily on documentation rather than impact.

In addition, excessive emphasis on compliance may create a “box-ticking” mentality, diverting attention from innovation and long-term value creation. Firms may allocate significant resources to reporting rather than to substantive improvements in environmental performance or social responsibility. Furthermore, compliance burdens may disproportionately affect smaller enterprises with limited administrative capacity. Policymakers therefore face the challenge of balancing regulatory rigor with proportionality and clarity.

Another important aspect of ESG compliance is its global heterogeneity. Different jurisdictions impose varying levels of regulatory stringency, and multinational corporations must navigate complex cross-border requirements. In some regions, ESG compliance is heavily regulation-driven, while in others it is primarily

influenced by investor expectations and market-based mechanisms. This diversity creates challenges for harmonization and comparability. International frameworks and voluntary standards attempt to reduce fragmentation, but differences in enforcement intensity and cultural attitudes toward regulation continue to shape compliance practices (Paola et al., 2025).

Despite its procedural nature, ESG compliance can act as a catalyst for broader cultural change. By institutionalizing transparency and accountability, compliance mechanisms may gradually shape organizational norms and expectations. Over time, what begins as regulatory conformity may evolve into deeper integration of sustainability values.

Commitment can be defined as an intention to perform a particular behaviour as a voluntary choice. In the organizational context, it also involves the presence of a process goal and the sharing of commitment among actors in order to achieve a common objective, thereby benefiting from social support and mutual accountability (Geller & Veazie, 2014).

ESG commitment represents an authentic, value-driven integration of sustainability into corporate strategy, governance, and organizational culture. In contrast to ESG compliance—which focuses on adherence to regulatory requirements and reporting—commitment is proactive and internally motivated, embedding sustainability into decision-making processes, performance systems, and long-term corporate objectives. While compliance is reactive and externally driven, aimed primarily at mitigating legal, financial, and reputational risks, ESG commitment is strategic and grounded in the belief that sustainability drives long-term value, resilience, and legitimacy. Organizations characterized by strong commitment integrate ESG considerations from the outset, influencing capital allocation, supply chains, and leadership incentives.

Key distinctions between the two approaches also emerge in terms of time horizon and stakeholder engagement. Compliance is typically associated with short-term reporting cycles, with stakeholder interaction largely limited to meeting disclosure requirements. By contrast, commitment adopts a long-term perspective, involving multi-year planning and ambitious sustainability targets. In this context, stakeholders

are engaged through shared values and leadership alignment, even in the absence of formal regulatory obligations.

It can be argued that ESG integration within corporate governance can follow two fundamentally different trajectories, illustrated in Table 1: a compliance-based approach or a commitment-based approach. In the compliance-based model, ESG implementation is primarily reactive and externally driven. Organizations adopt environmental, social, and governance practices in response to regulatory requirements, investor mandates, or reputational pressures. The emphasis is placed on meeting minimum disclosure standards, ensuring conformity with legal obligations, and avoiding sanctions or public criticism. ESG in this context functions largely as a risk management mechanism, designed to mitigate legal, financial, and reputational exposure. Policies, reporting frameworks, and internal controls are developed to demonstrate adherence, yet sustainability considerations may remain peripheral to core strategic decision-making.

By contrast, a commitment-based approach to ESG is proactive and strategically embedded within the organization. Rather than merely responding to external demands, firms integrate ESG principles into long-term planning, capital allocation, innovation processes, and performance evaluation systems. Sustainability becomes part of the corporate identity and value proposition. In this model, ESG is not limited to compliance reporting but is reflected in organizational culture, leadership priorities, and stakeholder engagement practices. The focus shifts from risk avoidance to value creation, recognizing that environmental stewardship, social responsibility, and sound governance contribute to resilience, competitiveness, and long-term profitability.

Table 1: Comparison between compliance-based and commitment-based ESG

Dimension	Compliance-based ESG	Commitment-based ESG
Strategic Orientation	Reactive	Proactive
Primary Driver	Legally driven	Strategically integrated
Time horizon	Short-term reporting cycles	Long-term perspective
Depth of Integration	Minimum disclosure	Integrated sustainability culture
Core Objective	Risk avoidance	Value creation orientation

Source: author

In summary, compliance may be conceptualized as a *push system* grounded in technical conformity, whereas commitment represents a *pull system* based on cultural alignment. This distinction is supported by the findings of Chen & Chen (Chen & Chen, 2019), which indicate that instrumental and moral motives contribute comparably to compliance, while moral motives exert a stronger influence on firms' commitment to sustainable practices. Furthermore, although compliance has a more pronounced effect on economic and environmental performance, commitment proves significantly more robust in enhancing environmental and social outcomes.

The determinants of ESG outcomes can be grouped into four broad categories. First, the level of economic and social development creates a context in which significant societal challenges can be openly recognized and addressed. Closely related to this is the political and regulatory framework: while the identification of key social issues is essential, meaningful progress often depends on regulatory intervention or policy support to ensure the implementation of appropriate measures. Third, financial market conditions may serve as an additional mechanism for promoting socially beneficial initiatives, particularly when such actions are aligned with financial incentives or profitability objectives. Finally, specialized investment strategies focused on responsible and sustainable impact—commonly referred to as socially responsible investment (SRI)—represent a further driver encouraging firms to enhance their ESG performance (Daugaard & Ding, 2022).

The context shaped by societal challenges inherently reflects the fundamental characteristics of a given society, including its cultural attributes, which in turn influence the regulatory framework, even in the presence of increasing global regulatory convergence. These findings support the broader argument that the transition from ESG compliance to ESG commitment cannot be achieved solely through regulatory mechanisms or formal governance structures. Rather, cultural dimensions—both organizational and national—play a decisive role in shaping how ESG principles are perceived, internalized, and implemented. Consequently, efforts to facilitate this transition should not rely exclusively on standardized regulatory approaches but should instead incorporate culturally sensitive strategies tailored to specific institutional and societal contexts.

The relationship between ESG sustainability and culture can therefore be examined along multiple dimensions, most notably at the organizational and national levels.

3 Cultural Differences Perspective: Explaining ESG Governance at the National Level

According to Geert Hofstede (Hofstede, 2008), culture can be defined as the collective programming of the mind that distinguishes the members of one group or category of people from another. In this sense, national culture shapes social norms and standards, influencing how individuals think and behave. It also affects beliefs, values, expectations, and economic outcomes, largely because it underpins attitudes toward economically relevant phenomena such as social capital, unethical behaviour, and preferences for redistribution. By extension, the extent to which societies value socially responsible behaviour—or penalize misconduct—may vary significantly across cultural contexts (Shin et al., 2023).

Geert Hofstede initially identified four measurable cultural dimensions, later expanded to six. These include (Hofstede, 2008; Sutrisno & Dularif, 2020) individualism–collectivism, power distance, masculinity–femininity, uncertainty avoidance, long-term versus short-term orientation, and indulgence versus restraint. However, a substantial body of research on the relationship between culture and ESG sustainability (Bae et al., 2012; Liaqat et al., 2026) focuses on four core dimensions – individualism, uncertainty avoidance, power distance, and long-term orientation – which are also adopted in the present study.

Individualism captures the extent to which individuals are integrated into groups and the degree to which autonomy and self-interest are prioritized over collective goals. In individualistic societies, generalized trust tends to extend beyond close social networks, fostering confidence in public institutions. Such trust contributes to stronger ESG outcomes by enhancing institutional quality, improving governance, and encouraging environmentally responsible behaviour. Moreover, individualistic cultures promote decision-making based on economic fundamentals rather than social ties, thereby reducing herd behaviour. Although stakeholders in these contexts may prioritize personal benefits, ESG practices are often adopted once their financial advantages become evident, positioning ESG not only as a societal objective but also as a strategic instrument for value creation and profitability.

Uncertainty avoidance reflects the degree to which societies tolerate ambiguity and risk. High uncertainty avoidance is associated with a preference for strict rules and formalized structures, often leading to regulatory-driven ESG adoption. While this may result in higher ESG scores, such adoption is frequently compliance-oriented and motivated by risk avoidance rather than genuine strategic integration. This “box-ticking” approach limits broader benefits such as stakeholder engagement and reputational gains, thereby weakening ESG’s contribution to financial stability.

Power distance refers to the extent to which inequality and hierarchical structures are accepted within a society. In high power distance environments, lower levels of social trust and weaker expectations regarding corporate responsibility tend to prevail, often resulting in less effective ESG performance. Reduced trust increases transaction costs and undermines financial stability, while also discouraging investment in ESG initiatives and increasing operational costs. In contrast, low power distance societies exhibit higher levels of trust, which facilitate responsible risk-taking, support innovation, and improve access to finance, thereby creating more favourable conditions for ESG investment.

Long-term orientation reflects the extent to which societies prioritize future outcomes over immediate gains. In long-term-oriented cultures, values such as persistence and thrift encourage investments in sustainability and align corporate strategies with long-term stakeholder interests. This orientation can strengthen the ESG–stability relationship by promoting forward-looking risk management, including the mitigation of long-term environmental and financial risks. At the same time, a strong future orientation may lead firms to place less emphasis on immediate transparency, potentially weakening stakeholder trust.

The relationship between culture and ESG sustainability can also be examined at the national level along two main dimensions: first, the influence of national culture on the perception and interpretation of values underlying ESG sustainability; and second, its impact on how sustainability disclosures are interpreted. With regard to the first dimension, existing research demonstrates a clear link between national culture and values associated with corporate social responsibility and ESG (Lafraia & Dias, 2024). Societies tend to distinguish between two overarching categories of corporate motives for engaging in environmental and social initiatives (van Prooijen et al., 2021): public-serving motives, oriented toward collective welfare and external

stakeholders, and firm-serving motives, focused on organizational benefits such as financial performance.

Regarding the second dimension, empirical findings suggest that the financial returns associated with ESG engagement vary across countries due to differences in how stakeholders evaluate and appreciate ESG performance (Shin et al., 2023). In cultures characterized by high individualism or masculinity, ESG performance is more explicitly recognized and more strongly linked to financial outcomes. By contrast, in cultures with high power distance or uncertainty avoidance, ESG efforts are less likely to translate into improved financial performance. Similarly, evidence indicates that while ESG performance can enhance bank stability (Liaquat et al., 2026), this effect is more pronounced in individualistic cultures, whereas high levels of uncertainty avoidance, power distance, and long-term orientation may attenuate this relationship.

The connection between Hofstede's cultural dimensions and ESG implication are being an objective of some researches with controversial results mostly because of limited scope of cultures included (Jacobs et al., 2016; Khlif, 2016; Khlif et al., 2015).

A growing body of research also examines the influence of national culture on broader accountability mechanisms and rule compliance beyond sustainability. For example, cultural dimensions such as individualism and uncertainty avoidance have been found to be positively associated with tax compliance (Kapıcıoğlu & Ekelik, 2026), suggesting that cultural factors systematically shape adherence to formal rules.

In addition to Hofstede's framework, the distinction between high-context and low-context cultures, introduced by Edward T. Hall (Hall, 1976), provides a valuable analytical lens for understanding cross-cultural differences in communication patterns, trust formation, and institutional design. This perspective offers important insights into how ESG principles are interpreted, legitimized, and operationalized across different societal contexts.

High-context cultures rely on implicit communication, shared experiences, and relational trust, with informal norms often guiding behaviour more strongly than formal rules. In such settings, ESG legitimacy frequently depends on endorsement by respected leaders, community figures, or professional networks. Narrative

communication, symbolic actions, and relational accountability play a central role, while formal reporting may be less emphasized. ESG commitment can diffuse rapidly when sustainability values are embedded within social networks; however, in the absence of relational support, formal ESG rules may have limited impact.

By contrast, low-context cultures emphasize explicit communication, codified rules, and contract-based trust. ESG implementation in these environments is typically based on measurable indicators, standardized reporting, and external verification. Transparency, detailed performance metrics, and structured compliance systems reinforce accountability. Although initial ESG adoption may be compliance-driven, the availability of transparent performance data can foster longer-term commitment.

Both cultural models present distinct advantages and limitations: high-context systems facilitate normative alignment and internalization of values, whereas low-context systems ensure transparency, comparability, and accountability. Effective ESG strategies should therefore account for these cultural communication patterns, balancing relational legitimacy with formal governance mechanisms in order to promote substantive and enduring sustainability commitment.

4 Integrating Cross-Cultural, Institutional, and Stakeholder Perspectives: Explaining ESG Compliance versus Commitment at the Organizational Level

At the organizational level, the relationship between culture and ESG sustainability can be conceptualized through the prism of several management theories. A robust theoretical explanation of ESG adoption – particularly the distinction between compliance and commitment – can be developed by integrating insights from cross-cultural management with institutional theory, stakeholder theory, and the Corporate Social Responsibility (CSR) literature. Such an approach allows for a multi-level understanding of how national culture shapes organizational behaviour, not in isolation, but through its interaction with institutional pressures and stakeholder expectations.

Cross-cultural management provides the foundational premise that managerial cognition, organizational practices, and strategic priorities are deeply embedded in national cultural systems. Scholars such as Geert Hofstede (Sutrisno & Dularif,

2020) demonstrate that values such as individualism, collectivism, long-term orientation, and universalism systematically vary across societies and influence how organizations interpret their roles and responsibilities. These cultural frameworks shape not only internal decision-making processes but also how firms perceive external demands, including those related to ESG sustainability.

However, culture by itself does not fully determine organizational behaviour. Institutional Theory offers an essential complementary perspective by explaining how organizations react to wider systems of rules, norms, and societal expectations. Building on the work of John W. Meyer and Ronald L. Jepperson (Jepperson & Meyer, 2021), organizations are understood as actors striving to attain legitimacy within their institutional contexts. Legitimacy, in turn, refers to a broadly shared perception that an entity's actions are appropriate and acceptable within a socially constructed system of norms, values, and beliefs (van Prooijen et al., 2021). Within such environments, organizations are subject to three main types of pressures: coercive (such as regulatory requirements), normative (arising from professional standards), and mimetic (stemming from imitation under conditions of uncertainty).

Within this framework, national culture can be understood as a form of informal institution that shapes how these pressures are interpreted and enacted. Building on the work of W. Richard Scott, culture is embedded within the normative and cultural-cognitive pillars of institutions (Scott, 1995). It influences what is considered appropriate, legitimate, and desirable behaviour. Consequently, while firms across different countries may face similar formal ESG regulations or global standards, their responses may differ significantly depending on culturally embedded values.

This interaction between institutional pressures and cultural context provides a useful explanation for the variation between ESG compliance and ESG commitment. ESG compliance typically reflects a response dominated by coercive pressures. Firms adopt ESG practices to meet regulatory requirements, satisfy reporting standards, or avoid reputational risks. In such cases, ESG remains external to the core strategy of the firm, functioning as a mechanism of legitimacy rather than a driver of value creation. This form of adoption is more likely in cultural contexts characterized by high power distance and high uncertainty avoidance, where adherence to formal rules and hierarchical authority is emphasized.

In contrast, ESG commitment reflects a deeper internalization of sustainability principles, driven by normative and cultural-cognitive alignment. Here, firms integrate ESG considerations into their core strategic objectives, decision-making processes, and organizational identity. This form of adoption is more likely in cultural contexts that emphasize collectivism, long-term orientation, and values such as universalism and benevolence. In these settings, sustainability is not perceived as an external imposition but as a natural extension of shared societal values.

The effectiveness of ESG integration within corporate governance structures is closely linked to the concept of tone at the top. While ESG frameworks provide formal standards, reporting requirements, and performance metrics, their substantive implementation largely depends on the ethical climate and value orientation established by senior leadership. As highlighted in the COSO-based understanding of internal control, leadership behaviour shapes organizational culture and influences how formal rules are interpreted and applied in practice. Consequently, the distinction between symbolic and substantive ESG adoption can often be traced to the signals transmitted by top management.

Tone at the top can be understood as a sustained and clearly communicated example set by leadership, gradually shaping employees' behaviour and expectations. As noted in the literature, the organizational climate regarding control awareness and expected standards of conduct depends heavily on the signals transmitted throughout hierarchical levels. Cunningham (Cunningham, 2005) defines tone at the top as the shared set of values established by senior management and reflected primarily in their actions. Similarly, it has been described as the "DNA of integrity," signifying consistent adherence to high moral and professional standards.

The theoretical justification for its significance is grounded in Fazio's (Fazio, 1990) Motivation and Opportunity as Determinants (MODE) model, which distinguishes between spontaneous and deliberate behaviour. Empirical research demonstrates that when intrinsic motivation is weak, leadership cues strongly influence professional conduct. Consequently, tone at the top plays a crucial role in shaping organizational ethics, performance standards, and long-term behavioural norms through both positive signals—such as zero tolerance for fraud—and negative signals, including tolerance of unethical practices.

Stakeholder theory further enriches this analysis by focusing on the relational dimension of organizations. Introduced by R. Edward Freeman, the stakeholder approach defines stakeholders as any group or individual that can affect or is affected by the achievement of an organization's objectives (Freeman & McVea, n.d.). It shifts the focus of strategic management from a narrow emphasis on shareholder value to a broader consideration of multiple stakeholder interests. Importantly, stakeholder theory emphasizes that long-term organizational success depends on the effective management and integration of these relationships.

The relevance of stakeholder theory to ESG lies in its normative foundation: it assumes that firms have responsibilities not only to shareholders but also to employees, customers, communities, and the natural environment. However, the relative importance assigned to different stakeholders is not universal; it is shaped by cultural context. For example, in collectivist societies, community and societal stakeholders may be prioritized, facilitating ESG commitment. In more individualistic contexts, stakeholders may be evaluated primarily in terms of their economic relevance, reinforcing a compliance-oriented approach.

The CSR literature provides additional insight into how these dynamics manifest in practice. As highlighted by scholars such as Dirk Matten and Jeremy Moon, there is a distinction between "implicit" and "explicit" CSR (Matten & Jeremy Moon, 2008). Implicit CSR refers to practices that are embedded in institutional frameworks and cultural norms, often observed in European contexts where social responsibility is integrated into the fabric of business-society relations. Explicit CSR, more common in Anglo-American contexts, involves voluntary, strategic initiatives that are often communicated externally. This distinction aligns closely with the compliance versus commitment continuum in ESG. Implicit CSR environments, characterized by strong institutionalization and cultural alignment, are more conducive to ESG commitment. In contrast, explicit CSR environments may encourage firms to adopt ESG practices as visible signals of responsibility, often driven by reputational concerns rather than intrinsic values.

Taken together, these theoretical perspectives suggest that ESG adoption is best understood as the outcome of a complex interaction between institutional pressures, cultural values, and stakeholder relationships. Cross-cultural management provides the lens through which differences in values and cognition are understood;

institutional theory explains how these differences shape responses to external pressures; stakeholder theory highlights the relational mechanisms through which ESG is enacted; and CSR literature illustrates how these dynamics are expressed in practice.

Importantly, this integrated framework also highlights that ESG commitment is not simply a function of stronger regulation or better governance. Rather, it depends on the alignment between ESG principles and the underlying cultural and institutional context. Where such alignment exists, firms are more likely to internalize sustainability as a core strategic objective. Where it does not, ESG is more likely to remain a compliance-driven activity, focused on meeting external expectations without fundamentally transforming organizational behaviour.

In this sense, the transition from ESG compliance to ESG commitment can be conceptualized as a shift from external adaptation to internal integration. It reflects not only changes in regulatory environments but also deeper transformations in values, norms, and stakeholder relationships. Understanding this shift requires a theoretically pluralistic approach, combining insights from cross-cultural management, institutional theory, stakeholder theory, and CSR. Such an approach provides a more nuanced and comprehensive explanation of why ESG practices vary across contexts and how they can evolve toward more substantive and value-driven forms of sustainability.

5 ESG Embedding Mechanisms from compliance to commitment: An Integrative Perspective

Building on the distinguishing features of ESG compliance and ESG commitment, the key characteristics of national cultures, and the mechanisms through which ESG sustainability is internalized as part of organizational culture, a conceptual model of their interrelationships can be derived. An understanding of the cultural context—particularly Geert Hofstede’s cultural dimensions—and their linkage to ESG implementation mechanisms, including regulatory effectiveness, tone at the top, stakeholder activism, long-term investment orientation, reporting preferences, and overall ESG orientation, informs the conceptual model presented below.

5.1 Power Distance and Authority-Based ESG Compliance

In high power distance societies, authority is rarely questioned, and ESG adoption relies on formal compliance with strong, centrally enforced regulations. Stakeholder activism is limited, making top leadership critical in setting sustainability priorities, with reporting typically formal and rule-based. Long-term ESG investment depends on directives from senior authorities.

Conversely, low power distance cultures favor equality and participatory decision-making. ESG engagement is driven by active stakeholders, the tone at the top is shared, long-term investment is strong, and reporting emphasizes transparency. Here, ESG adoption reflects commitment through participation rather than hierarchical compliance.

5.2 Uncertainty Avoidance and Regulatory Formalism

High uncertainty avoidance cultures prioritize stability and detailed regulation, resulting in comprehensive ESG legislation and compliance-driven initiatives. Organizations rely on formal rules, standardized reporting, and risk mitigation, with the tone at the top reinforcing policies rather than visionary leadership. Stakeholder activism is moderate, and long-term ESG investment is cautious, with reporting favoring detailed, checklist-style disclosures.

In contrast, low uncertainty avoidance societies tolerate ambiguity and encourage experimentation. ESG frameworks are principles-based, allowing innovation and strategic leadership. Stakeholder activism and long-term investment are strong, while reporting emphasizes flexible, narrative-driven disclosures over prescriptive rules.

5.3 Long-Term Orientation and Strategic Sustainability

High long-term orientation cultures embed ESG deeply, emphasizing perseverance, intergenerational responsibility, and strategic alignment with national development. Legislative effectiveness is moderate, with ESG often integrated into broader policy rather than strictly enforced. Leadership adopts a strategic tone at the top, long-term ESG investment is high, reporting is integrated, and ESG orientation is commitment-driven, reflecting intrinsic organizational values.

In contrast, short-term oriented cultures prioritize immediate results. ESG legislation is less effective, leadership focuses on financial metrics, long-term investment is limited, and reporting is minimal or compliance-based. ESG initiatives are tactical, pursued mainly for quick financial or reputational gains.

5.4 Collectivism, Individualism, and Legitimacy Sources

Collectivist societies emphasize group welfare, granting ESG initiatives high social legitimacy. Leadership strongly embodies collective values, legislative frameworks align with societal norms, long-term ESG investment is high, and reporting favors integrated narratives. ESG orientation reflects societal alignment.

By contrast, individualistic cultures derive legitimacy from legal compliance and market performance. Stakeholder activism is high, the tone at the top is moderate, long-term ESG investment depends on financial incentives, and reporting focuses on KPIs, resulting in an investor-driven ESG orientation.

5.5 Communication Context and Reporting Style

High-context cultures emphasize implicit communication, relationships, and shared understanding. ESG reporting is narrative, symbolic, and value-driven, with leadership signaling priorities through actions. Governance relies on trust and social norms, and ESG orientation is norm-driven, shaped by expectations and reputation.

Low-context cultures prioritize explicit rules, measurable outcomes, and formal accountability. ESG reporting is quantitative and metric-based, stakeholder activism is high, and long-term ESG investment is data-driven. ESG orientation is metric-driven, focusing on transparency, comparability, and performance.

5.6 Integrative Implications

The interaction between cultural dimensions and ESG embedding mechanisms, illustrated in Table 2, demonstrates that sustainability governance cannot be universally standardized. Legislative effectiveness, tone at the top, stakeholder activism, and reporting preferences are all culturally contingent. In high power distance and high uncertainty avoidance contexts, ESG tends to be compliance-

driven and authority-based. In low power distance and low uncertainty avoidance settings, participatory and innovation-driven models prevail. High long-term orientation and collectivism foster deep, commitment-driven ESG integration, whereas short-term orientation and strong individualism often produce tactical or investor-driven approaches.

Table 2: Cultural Dimensions and ESG Embedding Mechanisms

Cultural Dimensions	Legislative Effectiveness	Tone at the Top	Stakeholder Activism	Long-Term ESG Investment	Reporting Preference	Likely ESG Orientation
High Power Distance	Very high	Critical	Low	Moderate	Formal	Compliance via authority
Low Power Distance	Moderate	Shared	High	High	Transparent	Commitment via participation
High Uncertainty Avoidance	High	Important	Moderate	Moderate	Detailed rules	Compliance-driven
Low Uncertainty Avoidance	Moderate	Strategic	High	High	Principles-based	Innovation-driven
High Long-Term Orientation	Moderate	Strategic	Moderate	Very high	Integrated	Commitment-driven
Short-Term Orientation	Low	Financial focus	Variable	Low	Minimal	Tactical ESG
Collectivism	High social legitimacy	High	Moderate	High	Integrated	Societal alignment
Individualism	Legal legitimacy	Moderate	High	Market-based	KPI-focused	Investor-driven
High-Context Culture	Relationship-based	Symbolic leadership	Moderate	Variable	Narrative	Norm-driven
Low-Context Culture	Rule-based	Governance-based	High	High	Quantitative	Metric-driven

Source: author

Importantly, tone at the top functions as a cross-cutting moderating mechanism across all cultural contexts. In hierarchical cultures, it reinforces compliance through authority. In participatory cultures, it shapes shared commitment. In innovation-oriented environments, it frames ESG as a strategic opportunity. Thus, leadership signals translate external regulatory and cultural expectations into organizational behaviour.

Overall, understanding the cultural foundations of ESG embedding enhances both academic insight and policy design. Policymakers must tailor regulatory strategies to cultural contexts, leveraging authority in hierarchical systems, participation in egalitarian societies, and market incentives in individualistic environments. Similarly, corporate leaders must recognize that ESG success depends not only on formal frameworks but also on culturally aligned governance practices. By integrating cultural dimensions into ESG analysis, organizations can move beyond symbolic compliance toward substantive, context-sensitive sustainability transformation.

Figure 1 presents an integrative conceptual model linking national cultural dimensions to ESG implementation outcomes. It illustrates how cultural context shapes key organizational embedding mechanisms, which in turn determine whether ESG is adopted as compliance-driven or internalized as strategic commitment. The model conceptualizes ESG adoption as a continuum from rule-based conformity to value-driven integration.

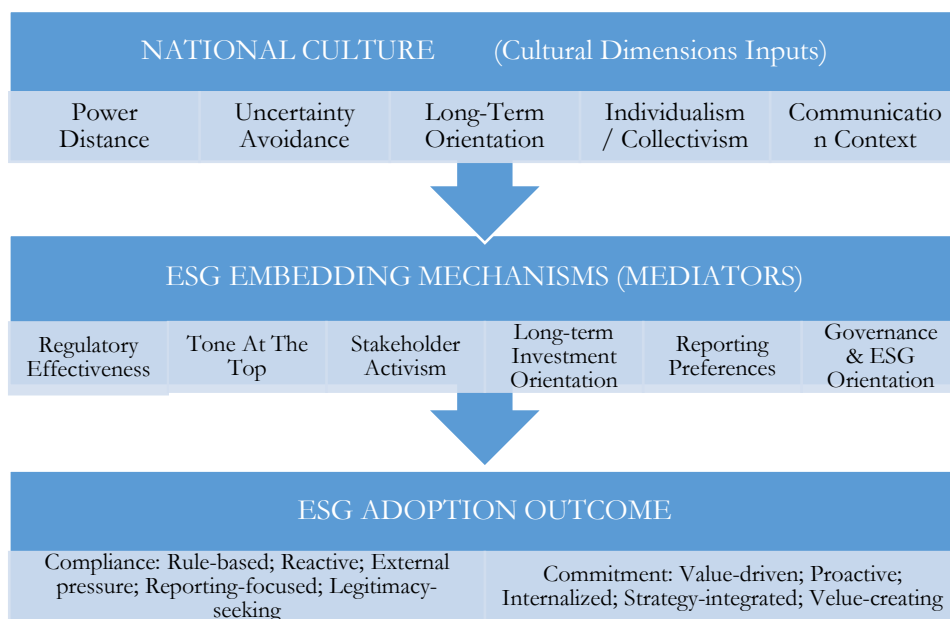


Figure 1: Conceptual Model of ESG Embedding: From Compliance to Commitment

Source: author

6 Conclusion

The institutionalization of ESG practices is deeply shaped by the interplay between cultural dimensions and governance mechanisms. Compliance alone is insufficient; true sustainability requires alignment between societal values, corporate leadership, and regulatory frameworks. Cultural traits—such as power distance, individualism, uncertainty avoidance, and long-term orientation—determine how ESG initiatives gain legitimacy, are implemented, and transition from procedural adoption to strategic commitment. Multinational corporations and policymakers must therefore design ESG strategies and regulations that are culturally sensitive, balancing global principles with local adaptation. Tone at the top, participatory governance, and context-aware reporting emerge as critical mechanisms for embedding ESG effectively across diverse environments.

The distinction between compliance-based and commitment-based ESG constitutes a meaningful conceptual contribution to the literature on corporate sustainability. Integrating cultural dimensions into this framework provides a nuanced and analytically valuable perspective on how ESG practices are interpreted and implemented across contexts. Together, these insights enhance our understanding of the conditions under which ESG evolves from formal compliance to genuine strategic commitment.

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BLOCKCHAIN AS A GOVERNANCE INFRASTRUCTURE FOR ESG COMPLIANCE IN EUROPEAN SUPPLY CHAINS

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This paper examines how blockchain technologies are reshaping governance and transparency in European supply chains and assesses whether these changes can enhance ESG compliance under the Corporate Sustainability Reporting Directive (CSRD) and the Corporate Sustainability Due Diligence Directive (CSDDD). Drawing on a structured conceptual synthesis of academic literature, EU regulatory documents, and publicly documented industry cases, the paper argues that blockchain can support more data-driven, traceable, and auditable oversight by replacing fragmented documentation with continuous, tamper-resistant information flows. These capabilities are particularly relevant to the environmental and governance dimensions of ESG, as they can enhance emissions tracking, chain-of-custody verification, and audit-trail reliability. However, blockchain's contribution remains uneven and depends on the governance of permissioned consortia, the quality of input data, interoperability challenges, and firms' willingness to share information. Its contribution to social sustainability is more limited, as many labor-related risks are difficult to capture solely through digital records. The paper concludes that blockchain can serve as an enabling governance infrastructure for European ESG regulation, but not as a standalone solution. Its effectiveness depends on regulatory clarity, interoperable digital standards, and sustained collaboration across supply chain actors.

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1 Introduction

Businesses find it challenging to monitor environmental, social, and governance (ESG) issues across multiple tiers of suppliers because of the increasing fragmentation, geographical dispersion, and operational opacity of global supply chains. According to Zamfir (2020), this structural complexity has widened information gaps between firms and their upstream partners. The European Union enacted a comprehensive legislative framework to improve corporate accountability and transparency. The Corporate Sustainability Reporting Directive (CSRD), which introduces the double materiality principle and requires companies to disclose both financial, material ESG information and sustainability impacts relevant to society, is a key component of this framework. It also extends mandatory sustainability reporting to a much broader set of companies (European Commission, 2025). Europe is becoming one of the most demanding regions for ESG-related supply chain governance due to these regulatory developments, which signal increased expectations for traceability, data quality, and disclosure accuracy.

Traditional governance methods have inherent limitations that undermine their effectiveness in complex global supply chains, despite the widespread use of sustainability audits, certifications, supplier questionnaires, and voluntary reporting schemes. OECD (2018) notes that voluntary due diligence often relies on self-reported and selectively verified information, resulting in persistent transparency gaps. European Commission (2023) defines greenwashing as a widespread practice in which businesses exaggerate, misrepresent, or fabricate environmental claims to appear more sustainable than they are. These shortcomings directly contribute to the persistence of greenwashing. Greenwashing is a structural governance failure that distorts market transparency, misleads investors and customers, and undermines the credibility of ESG reporting systems. It is not merely a communication issue.

Regulatory agencies have increasingly issued warnings about the dangers of making false sustainability claims. According to ESMA (2024), false ESG disclosures threaten both investor protection and market integrity, and greenwashing can occur at any stage of the sustainable investment value chain. ESMA's (2024) findings indicate that sustainability statements often omit valuable information, use vague language, or lack verifiable evidence—issues that are difficult for traditional audits and certifications to detect. As the European Union shifts from voluntary corporate

social responsibility to mandatory due diligence under measures such as the Corporate Sustainability Due Diligence Directive (CSDDD), these limitations become even more significant. Under this new regulatory framework, businesses must demonstrate ongoing, evidence-based oversight of environmental and human rights impacts throughout their entire value chains. Traditional governance tools were not designed to meet the demands for continuous, legally enforceable ESG oversight.

In this context, blockchain technology has attracted increased attention as a potential solution to ongoing accountability and transparency challenges in international supply chains. Conceptually, blockchain functions as a distributed and immutable ledger, enabling decentralized transaction verification and ensuring that recorded data cannot be altered retroactively. According to the European Commission (2022), these characteristics make blockchain particularly suitable for situations where multiple parties need to share information without relying on a single trusted intermediary. The integration of smart contracts, self-executing code embedded within the blockchain, further enhances governance by automating compliance checks, generating alerts, and enforcing predetermined rules without human intervention. This technical architecture supports end-to-end traceability, allowing businesses to track the origin, movement, and transformation of items at every stage of the supply chain.

Recent studies suggest that blockchain may reduce information asymmetries and support more reliable ESG data flows. Blockchain technology can provide reliable records of social and environmental performance, support more credible sustainability claims and reduce the risk of greenwashing. Similarly, the World Economic Forum (2020) argues that blockchain-enabled traceability can improve risk management, enable real-time monitoring, and encourage more ethical sourcing practices. Because blockchain enables the creation of tamper-resistant, auditable, and interoperable ESG data, it is increasingly considered in the European regulatory landscape as a technical supplement to CSRD-aligned reporting and CSDDD-aligned due diligence procedures. As regulatory demands for transparency increase, blockchain offers a viable, though challenging, path toward stronger and more verifiable ESG governance in European supply chains.

Despite significant excitement, conflicting empirical evidence remains regarding blockchain's actual impact on ESG outcomes. Systematic studies of blockchain implementations in sustainable supply chains often find that its theoretical advantages are not realized in practice. For example, Paliwal et al. (2020) identify persistent challenges, including data quality limitations, interoperability issues, and organizational readiness, which hinder the effective use of blockchain technology in real-world supply chains. Similarly, Munir et al. (2022) argue that while blockchain may enhance traceability and transparency, its ESG impact is often constrained by inadequate data inputs, inconsistent stakeholder engagement, and the absence of standardized sustainability indicators. Governance challenges further complicate implementation. European Commission (2022) reports that integrating blockchain into existing corporate reporting systems is obstructed by fragmented digital infrastructures, unclear data ownership rules, and a lack of harmonized regulatory guidance.

The European regulatory context is notably underexplored in the literature. Few studies specifically examine how blockchain's capabilities align with the reporting and due diligence requirements set by the CSRD and the CSDDD, even though blockchain is widely theorized as a tool for enhancing transparency. Most existing evaluations focus on conceptual benefits rather than assessing whether blockchain can generate auditable, standardized, and regulator-ready ESG data required by EU law. Similarly, the European Commission (2022) notes that blockchain's effectiveness largely depends on broader institutional and governance frameworks, suggesting that technological solutions alone cannot address systemic transparency shortcomings. This gap between conceptual promise and regulatory reality highlights the need for a more comprehensive, evidence-based assessment of blockchain's role in ESG-oriented supply chain governance, especially given Europe's increasingly stringent sustainability regulations.

This paper addresses the following research question: How can blockchain-based systems support sustainability-oriented supply chain governance within the European regulatory framework? This inquiry highlights the increasing need to assess both the technological potential of blockchain and its capacity to meet the evolving reporting and due diligence requirements in the European regulatory environment. The paper aims to clarify how blockchain can support more reliable, verifiable, and interoperable ESG-related data flows by synthesizing recent scholarly

literature and analyzing the changing institutional framework shaped by instruments such as the CSRD and CSDDD. At the same time, the investigation critically examines the constraints, implementation challenges, and unresolved governance issues that continue to limit blockchain's effectiveness in real-world supply chain scenarios. In doing so, the paper presents blockchain as a contingent and context-dependent governance tool, whose usefulness depends on broader institutional, organizational, and technological conditions, rather than as a deterministic solution.

The paper is structured as follows. Section 2 presents the theoretical and regulatory background, focusing on supply chain governance, information visibility, and the European ESG framework. Section 3 reviews the literature on traditional governance mechanisms and blockchain applications in supply chains, highlighting key limitations and contextual conditions. Section 4 describes the methodological approach, which is based on a structured conceptual synthesis. Section 5 discusses the implications of blockchain for sustainability-oriented supply chain governance and outlines directions for future research. Section 6 concludes by answering the research question, summarizing implications for policymakers, companies, and researchers, and outlining limitations and directions for future research.

2 Theoretical and regulatory background

2.1 Governance, Information Visibility, and ESG Requirements in European Supply Chains

In the academic literature on global production networks, governance refers to the institutional configuration through which firms coordinate interdependent activities, allocate responsibilities, and enforce standards across dispersed supplier ecosystems. Rather than a narrow managerial function, governance includes the rules, monitoring arrangements, and decision-making structures that determine how authority and risk are distributed along the chain. Classic global value chain theory emphasizes that these arrangements arise in response to transaction complexity, the codifiability of information, and supplier capabilities, resulting in varying degrees of oversight and control (Gereffi et al., 2005). Within European supply chains, these challenges are heightened by regulatory expectations that firms maintain continuous, evidence-based supervision of environmental and social impacts. As OECD (2018) notes, conventional due diligence practices often rely on self-reported or selectively

verified information, exposing systemic weaknesses in the mechanisms firms use to ensure responsible conduct.

A central difficulty arises from limited visibility into information across multi-tier networks. Scholars argue that without reliable access to upstream data, including production conditions and emissions metrics, firms struggle to identify risks or substantiate sustainability claims (Mol, 2015). This lack of verifiable information creates vulnerabilities that go beyond operational inefficiencies: it undermines the credibility of corporate reporting and enables misleading environmental or social assertions. European Commission (2023) explicitly links these informational gaps to the persistence of greenwashing, noting that unverifiable claims distort markets and erode stakeholder trust. Consequently, the ability to generate accurate, consistent, and auditable data has become a foundational requirement for effective oversight in European supply chains.

The European Union's evolving ESG regulatory framework formalizes these expectations. The CSRD expands mandatory sustainability disclosures and introduces the principle of double materiality, requiring firms to report both financially relevant ESG risks and their broader societal impacts (European Commission, 2025). The CSDDD further requires companies to identify, prevent, and mitigate adverse environmental and human rights impacts throughout their value chains, transforming due diligence from a voluntary practice into a legally enforceable obligation. Complementing these measures, the EU Taxonomy Regulation establishes a standardized classification system for environmentally sustainable activities, shaping how firms substantiate environmental performance and how investors assess sustainability risks. Scholars argue that the EU's recent sustainability regulation marks a shift from largely voluntary, sometimes symbolic CSR (CSR) commitments toward more substantive accountability, where firms must support sustainability reporting and due-diligence claims with verifiable, audit-ready evidence rather than intent alone (Hadro et al., 2025; Pantazi, 2024).

This regulatory framework highlights the structural interdependence between ESG compliance and firms' ability to generate reliable, high-quality data and maintain strong verification mechanisms throughout their supplier networks. Without systems that ensure data integrity, continuous monitoring, and credible audit trails, firms cannot meet the evidentiary standards required by CSRD, CSDDD, or the EU

Taxonomy. Regulatory bodies have emphasized this point. ESMA (2024) warns that insufficient information reliability and weak oversight structures create conditions in which greenwashing proliferates, threatening investor protection and undermining the legitimacy of sustainable finance markets. Academic research highlights that market-based sustainability governance—especially audit- and certification-centered oversight—often delivers only partial visibility and uneven accountability in multi-tier supply networks, limiting the ability to detect evolving risks and to demonstrate substantive improvements (LeBaron & Lister, 2021). These challenges have prompted growing interest in technological infrastructures that support more rigorous data assurance. In this context, blockchain has emerged as a potential tool for enhancing the reliability, auditability, and regulatory readiness of ESG-related information in European supply chains.

2.2 Basic Blockchain Concepts in Supply Chains

Blockchain is best understood as a distributed ledger architecture that restructures how information is recorded, validated, and exchanged across organizational boundaries. Unlike centralized databases, a distributed ledger is maintained collectively by multiple nodes, each holding synchronized copies of the same dataset. This structure reduces reliance on a single authority and enhances the resilience of information systems. A defining feature of blockchain is immutability: once a record is validated and appended to the ledger, it cannot be altered without leaving a detectable revision history. This integrity is enforced through consensus mechanisms, which allow participating nodes to agree on the validity of new entries before they are added. In supply chain applications, consensus typically relies on efficient algorithms suited to controlled environments rather than the open, energy-intensive protocols used in public networks. Smart contracts, self-executing code embedded within the ledger, extend these capabilities by automating predefined rules, enabling conditional payments, compliance checks, and event-triggered notifications without manual intervention (European Commission, 2022; World Economic Forum, 2020).

These technical properties provide several capabilities directly relevant to ESG-oriented supply chain oversight. First, blockchain enables comprehensive product and process monitoring by linking each logistical or production event to a

tamper-resistant digital record. This allows firms to reconstruct the complete history of an item's movement and transformation, enhancing the verifiability of sustainability claims. Second, the immutability of blockchain entries creates a secure audit trail for ESG-relevant data, such as emissions measurements, certifications, or due diligence findings. Because records cannot be retroactively modified, blockchain reduces opportunities for data manipulation and strengthens the evidentiary basis required for regulatory reporting. Third, smart contracts enable automated enforcement of contractual or regulatory obligations by embedding compliance logic directly into operational workflows. This can include automatic validation of supplier documentation, real-time alerts when environmental thresholds are exceeded, or the release of payments only after verified completion of sustainability-related milestones (Saber et al., 2018).

A central design distinction is the difference between public and permissioned blockchains. Public networks allow unrestricted participation and full visibility of transactions, features generally incompatible with commercial confidentiality, competitive sensitivities, and data protection requirements. As a result, most supply chain implementations use permissioned systems, where participation is limited to vetted organizations and data access is governed by consortium-level rules. Although permissioned architecture provides greater control, scalability, and alignment with privacy regulations, they also reintroduce elements of centralized coordination and limits the radical openness often associated with blockchain. Empirical studies show that firms frequently adopt consortium-based models that balance data accessibility with confidentiality, resulting in hybrid arrangements that enhance auditability and data integrity but do not provide full public transparency (European Commission, 2022; Lustenberger & Spychiger, 2025).

Clarifying these foundational concepts is essential for assessing whether blockchain's technical properties can support the evidentiary and procedural requirements imposed by CSRD and CSDDD.

3 Literature Review

3.1 Traditional Governance and Information Management in Supply Chains

Research on conventional supply chain oversight consistently highlights audits, certifications, supplier codes of conduct, and corporate reporting as the primary mechanisms firms use to monitor upstream practices. These tools emerged as standardized responses to growing concerns about labor abuses, environmental degradation, and ethical misconduct in global production networks. Scholars note that third-party audits and certification schemes were designed to provide external assurance and reduce information gaps between buyers and suppliers, while codes of conduct formalized expectations regarding labor, environmental, and ethical performance (LeBaron & Lister, 2021). Corporate sustainability reports became the main vehicle through which firms communicated their commitments and performance to external stakeholders. Together, these instruments formed the backbone of traditional supply chain governance throughout the 2000s and early 2010s.

Despite their widespread adoption, a substantial body of literature questions their effectiveness. Numerous studies argue that audit-based oversight struggles to detect systemic risks because it relies on periodic inspections, pre-announced visits, and documentation that can be selectively curated or falsified (LeBaron & Lister, 2021; OECD, 2018). Researchers have documented persistent information asymmetries between lead firms and upstream suppliers, noting that suppliers often have much more knowledge about production conditions than buyers, creating opportunities for opportunistic behavior and misrepresentation. Certifications and reporting schemes face similar challenges: they depend heavily on self-reported data, lack standardized metrics across industries, and often fail to capture conditions beyond first-tier suppliers. These weaknesses contribute to well-documented cases of fraud, concealment of labor violations, and inaccurate environmental disclosures. Scholars also highlight the technological limitations of traditional systems, which rely on siloed databases, fragmented IT infrastructures, and manual data collection processes, hindering real-time monitoring and reducing the reliability of reported information (Mol, 2015).

A recurring theme in this literature is that traditional governance instruments were not designed to meet the heightened expectations now imposed by ESG-oriented regulation, particularly in the European Union, where firms must demonstrate ongoing, evidence-based oversight rather than periodic compliance (Hadro et al., 2025; Mol, 2015; Pantazi, 2024).

3.2 ESG Pressures and the European Regulatory Context

Recent literature highlights a significant increase in expectations surrounding ESG performance within global supply networks. Analysts note that sustainability has shifted from a voluntary corporate initiative to an area shaped by investor scrutiny, civil society pressure, and increasingly stringent regulatory requirements. This change reflects a broader transformation in how firms are evaluated: stakeholders now require verifiable evidence of responsible conduct rather than general commitments or narrative reporting. Studies on the development of non-financial disclosure frameworks emphasize that European companies face growing demands for structured, comparable, and audit-ready sustainability information, driven by both market pressures and regulatory intervention (Hadro et al., 2025; Pantazi, 2024).

Within this changing landscape, the European Union has positioned itself at the forefront of institutionalizing ESG obligations. The EU's regulatory approach is distinctive because it integrates reporting, due diligence, and sustainable finance into a unified policy framework. The CSRD significantly increases the number of firms required to make mandatory sustainability disclosures and introduces detailed European Sustainability Reporting Standards (ESRS), which require companies to provide granular, verifiable data on environmental impacts, human rights risks, and governance practices (European Commission, 2025). In addition, the CSDDD requires firms to identify, prevent, and mitigate adverse impacts throughout their value chains, making due diligence a legal duty rather than a voluntary exercise. Researchers examining these developments note that the EU has moved decisively away from earlier soft-law approaches, replacing voluntary corporate social responsibility models with binding obligations that require demonstrable oversight of upstream operations (LeBaron & Lister, 2021).

Across the literature, there is broad recognition that these regulatory changes reflect a structural need for more reliable and interoperable sustainability data. Traditional reporting systems, built around self-disclosure, periodic audits, and fragmented IT infrastructures, struggle to meet the evidentiary standards required under CSRD and CSDDD. Studies consistently highlight persistent challenges such as inconsistent data formats, limited visibility beyond first-tier suppliers, and the absence of continuous monitoring mechanisms, all of which hinder firms' ability to produce the high-quality information demanded by regulators (Mol, 2015; OECD, 2018). While some authors view the EU's regulatory push as a catalyst for innovation in sustainability data management, others caution that compliance will remain difficult without significant technological and organizational transformation.

Debate continues over the feasibility of the EU's ambitions. Some commentators argue that the regulatory framework may outpace firms' operational capacities, especially in sectors with complex, multi-tier supply networks. Others contend that the move toward mandatory oversight is necessary because voluntary approaches have failed to achieve meaningful improvements in environmental and social outcomes. Despite these differing views, the literature agrees on one point: the EU's focus on verifiable, high-quality sustainability information creates strong incentives for firms to adopt new tools that enhance data integrity, monitoring capacity, and regulatory readiness.

3.3 Blockchain in Supply Chains (Global Evidence)

Research on blockchain applications in supply chains has expanded rapidly over the past decade, driven by the promise of more reliable information flows, enhanced auditability, and improved coordination across multi-tier networks. Early work focused on conceptualizing blockchain as a distributed ledger capable of recording product movements and transactional events in a tamper-resistant manner, thereby reducing opportunities for fraud and data manipulation (Saber et al., 2018). Subsequent studies documented a wide range of pilot projects across sectors such as food, pharmaceuticals, luxury goods, and logistics, where blockchain was used to verify product origins, authenticate certifications, and streamline documentation processes. These applications are often presented as solutions to long-standing problems of information asymmetry and fragmented data systems, with proponents

arguing that blockchain can accelerate audits, reduce counterfeiting, and strengthen the evidentiary basis of sustainability claims (World Economic Forum, 2020).

Despite these optimistic narratives, empirical findings are mixed. Several studies report that blockchain pilots often struggle to scale beyond initial testing due to interoperability challenges, inconsistent data inputs, and difficulties coordinating participation across diverse supply chain actors (Kouhizadeh et al., 2019). Network effects present a significant barrier: blockchain systems deliver value only when a critical mass of suppliers, logistics providers, and certification bodies adopt the same platform; a condition rarely met in fragmented global industries. Research also highlights that many blockchain deployments rely on permissioned consortia rather than open networks, which can limit data accessibility and reintroduce centralized control structures that blockchain was originally intended to circumvent (Lustenberger & Spychiger, 2025). These findings suggest that while blockchain can enhance data integrity within controlled environments, its broader governance implications remain uncertain.

On the one hand, blockchain is widely promoted as a transformative technology capable of reshaping supply chain oversight; on the other hand, empirical studies show that many implementations remain prototypes, with limited evidence of long-term operational impact. Some authors argue that blockchain's benefits are most pronounced in sectors with high regulatory pressure or strong incentives for verifiable provenance, such as food safety or pharmaceuticals. Others caution that blockchain alone cannot resolve underlying issues such as poor data quality, lack of supplier engagement, or misaligned incentives across the chain (Treiblmaier, 2018). These critiques underscore that blockchain's effectiveness depends not only on its technical architecture but also on the institutional, organizational, and economic conditions in which it is deployed.

These insights reinforce the view that blockchain should be examined as a context-dependent governance tool rather than a universal solution, particularly in regulatory environments such as the European Union.

3.4 Blockchain, Governance, and ESG Performance

A growing body of research examines blockchain not only as a logistical tool but also as a governance mechanism that can strengthen the credibility and reliability of sustainability information. Much of this work argues that blockchain's core attributes, tamper-resistant recordkeeping, decentralized validation, and automated rule enforcement, can enhance the evidentiary basis of environmental and social claims. Studies exploring sustainability-oriented blockchain applications suggest that distributed ledgers can support more reliable emissions accounting, verifiable labor documentation, and improved monitoring of resource use, thereby contributing to more robust ESG performance indicators (Park & Li, 2021; Qian et al., 2023). These contributions are often framed as responses to long-standing weaknesses in traditional oversight systems, particularly the reliance on self-reported data and the difficulty of verifying conditions beyond first-tier suppliers.

Several authors propose conceptual frameworks that integrate blockchain into broader sustainability governance models. For example, Saberi et al. (2018) describe how blockchain can reinforce responsible sourcing by improving data integrity and reducing opportunities for opportunistic behavior among suppliers. Similarly, Nikolakis et al. (2018) present the Evidence, Verifiability, and Enforceability (EVE) framework, which positions blockchain as a tool for strengthening the credibility of sustainability claims in global value chains. These frameworks agree that blockchain can enhance the reliability of ESG-related information by creating secure audit trails and enabling more consistent monitoring of environmental and social impacts. Other studies highlight the potential of smart contracts to automate compliance processes, such as verifying certifications or triggering alerts when sustainability thresholds are breached, thereby reducing the administrative burden associated with due diligence (World Economic Forum, 2020).

Despite these theoretical contributions, empirical evidence remains uneven. Many studies reporting positive ESG outcomes rely on simulations, prototypes, or single-case demonstrations rather than large-scale, longitudinal data. Research on real-world deployments frequently highlights persistent challenges, including high implementation costs, limited interoperability between blockchain platforms, and firms' reluctance to share sensitive information within distributed networks

(Lustenberger & Spychiger, 2025). These constraints often lead companies to adopt permissioned blockchain consortia, which provide greater control over data access but also reintroduce hierarchical governance structures that limit the openness and decentralization originally associated with blockchain. As a result, the extent to which blockchain improves sustainability outcomes varies significantly across contexts, and many projects do not progress beyond pilot stages.

The literature also reveals ongoing debate about blockchain's actual contribution to ESG performance. Some authors argue that blockchain can meaningfully reduce greenwashing by providing verifiable evidence of sustainability claims, particularly in sectors where provenance and certification are central to market value. Others caution that blockchain cannot compensate for poor data inputs, weak regulatory enforcement, or insufficient supplier engagement. Without reliable upstream data, blockchain risks becoming a sophisticated repository for inaccurate or incomplete information, a problem often summarized as "garbage in, garbage out." These critiques underscore that blockchain's effectiveness depends not only on its technical architecture but also on the institutional and organizational conditions in which it is embedded.

Taken together, this body of research highlights both the promise and the limitations of blockchain as a tool for ESG-oriented supply chain governance. The literature suggests that blockchain can enhance data integrity, strengthen verification mechanisms, and support more credible sustainability reporting, but its real-world impact remains contingent on adoption dynamics, regulatory alignment, and the quality of underlying data.

4 Methodology

This study uses a qualitative, concept-driven research design, grounded in a structured conceptual synthesis, to clarify how blockchain technologies intersect with emerging ESG obligations in European supply chains. Instead of conducting primary data collection, the analysis synthesizes insights from peer-reviewed scholarship, EU regulatory instruments, and publicly available industry materials to construct an integrated understanding of blockchain's governance implications. This approach is appropriate given the rapid evolution of both blockchain applications

and European sustainability regulation, as well as the need for a framework that brings these developments into dialogue.

The review draws on three categories of secondary sources selected for their direct relevance to the research question. First, peer-reviewed academic publications establish the theoretical foundations of blockchain, supply chain governance, transparency, and sustainability oversight. Second, EU regulatory and policy documents capture the institutional requirements shaping ESG reporting and due diligence in the European context, particularly those related to the CSRD and CSDDD. Third, publicly available industry reports, white papers, and implementation examples illustrate how blockchain-enabled traceability and monitoring have been framed or applied in practice.

Source identification followed a structured but non-systematic review approach. Relevant material was identified through targeted searches in Google Scholar, Scopus, and open-access repositories using combinations of terms such as “blockchain,” “supply chain,” “traceability,” “auditability,” “ESG,” “sustainability reporting,” “CSRD,” “CSDDD,” and “Europe.” The review focused primarily on material published between 2015 and 2025, reflecting the period when blockchain applications in supply chains expanded, and the European ESG regulatory framework became significantly more developed. Additional sources were identified through backward citation tracing from highly relevant academic and institutional publications.

Selection was based on thematic relevance rather than exhaustive coverage. Academic sources were prioritized when they offered conceptual clarity, theoretical framing, or synthesis of implementation challenges. Regulatory and institutional documents were prioritized when they clarified reporting, assurance, and due diligence expectations relevant to European firms. Industry materials were used more selectively, mainly for illustrative purposes rather than as independent evidence of effectiveness, to avoid overstating the empirical maturity of blockchain deployments.

The analytical process followed three steps. First, the literature was reviewed to identify blockchain’s core capabilities relevant to supply chain oversight, including secure recordkeeping, improved data verifiability, and automated rule enforcement.

Second, these capabilities were conceptually mapped to the environmental, social, and governance (ESG) dimensions to assess how blockchain could support compliance with CSRD and CSDDD requirements. Third, the study compared blockchain's theoretical potential with evidence from real-world deployments, highlighting the gap between conceptual claims and operational outcomes. Illustrative examples from publicly documented implementations clarify how blockchain functions in practice, without using a formal case study methodology.

This methodological approach allows the paper to connect the technological characteristics of blockchain with the institutional evolution of European sustainability governance. By integrating regulatory analysis with technological and organizational perspectives, the study provides a structured foundation for evaluating whether blockchain can enhance the reliability, auditability, and regulatory readiness of ESG-related information in European supply chains.

The aim of this approach is therefore not to provide a formal systematic review or a case-based evaluation, but to develop a transparent, analytically structured synthesis of how blockchain's governance capabilities align with the evidentiary demands of emerging European ESG regulations.

5 Analysis and Discussion: Governance Implications of Blockchain for ESG Compliance

5.1 Blockchain as a Governance Infrastructure in European Supply Chains

Blockchain introduces a series of structural changes in how firms coordinate, monitor, and verify activities across supply networks, with direct implications for ESG-oriented governance in the European regulatory environment. Traditional oversight mechanisms in supply chains rely primarily on ex post audits and fragmented documentation, offering limited visibility into upstream operations and delayed detection of ESG-related risks (OECD, 2018).

A second governance transformation involves the shift from siloed, paper-based information systems to shared digital infrastructures. In many supply chains, sustainability-relevant data remain dispersed across incompatible databases and

proprietary platforms, limiting firms' ability to reconstruct a reliable chain of custody. Blockchain-based architectures address this fragmentation by enabling authorized participants to access a synchronized ledger, reducing duplication and strengthening the consistency of recorded information. For European firms operating under CSRD requirements, such consolidation is particularly relevant, as it supports audit-ready disclosures and improves the interoperability of ESG-related data across organizational boundaries. Smart contracts add a governance layer by embedding rules directly into digital workflows. By automating the validation of documentation, issuing threshold-based alerts, or enabling conditional execution of contractual obligations, smart contracts can implement due diligence requirements more consistently and traceably. In the context of the CSDDD, where firms are expected to demonstrate proactive risk mitigation rather than reactive compliance, such automated mechanisms may support more systematic enforcement of sustainability requirements across supplier networks. However, their effectiveness ultimately depends on the quality of input data and the governance arrangements that define how rules are designed, monitored, and revised.

Blockchain also enhances the verifiability of the chain of custody information by generating tamper-resistant records of product movements and process-level events. Each transaction or transformation is time-stamped and cryptographically secured, creating a durable audit trail that can substantiate claims related to origin, environmental performance, or labor conditions. This capability addresses a central weakness of traditional governance systems, which often rely on unverifiable supplier declarations or documentation that can be selectively curated. In contrast, blockchain-based records provide a more robust evidentiary foundation for sustainability reporting and reduce the risk of greenwashing, an issue repeatedly highlighted by European regulators (ESMA, 2024).

However, blockchain does not eliminate governance challenges; rather, it reconfigures them. Most supply chain implementations rely on permissioned blockchain consortia rather than open public networks. These consortia introduce new forms of network governance in which participating firms collectively determine membership rules, data-access rights, and validation procedures. While this model enhances confidentiality and aligns with European data-protection requirements, it also recentralizes authority within a smaller group of dominant actors. Decisions about who controls validator nodes, who can view specific data

fields, and how consensus is reached become critical governance questions in their own right. Power asymmetries may persist if lead firms dictate consortium rules or restrict access to sensitive information, potentially limiting the democratizing potential often attributed to blockchain technologies (Lustenberger & Spychiger, 2025).

Overall, blockchain enables more continuous monitoring, improved data integrity, and automated rule enforcement, but it also introduces new governance arrangements that require careful institutional design. These dynamics are central to evaluating blockchain's contribution to ESG compliance under the CSRD and CSDDD, where regulatory alignment depends not only on technological capability but also on control, access, and accountability structures.

5.2 Blockchain and Transparency as a Governance Outcome

Blockchain's contribution to information visibility is often cited as one of its most significant governance effects in supply chains. By enabling more integrated and auditable records of product movements and sustainability-related events, blockchain addresses long-standing transparency challenges associated with fragmented documentation systems. This capability is particularly important in the European context, where firms must provide reliable, audit-ready ESG data under the CSRD and CSDDD.

A useful example is provided by blockchain-based food traceability initiatives, which use distributed ledgers to record product origin, batch movements, certification events, and handovers across multiple supply chain stages. In these settings, blockchain does not merely store documentation; it creates a shared, time-stamped chain of custody that allows firms and auditors to reconstruct product provenance more quickly and consistently than fragmented paper-based systems. This example is particularly relevant to the European ESG context because it demonstrates how blockchain can enhance auditability, reduce information gaps among supply chain participants, and strengthen the evidentiary basis for sustainability-related claims. At the same time, these initiatives show that the benefits of traceability depend on reliable upstream data entry, agreed participation rules, and interoperability with existing organizational systems.

A central mechanism is the creation of end-to-end traceability across supply networks. When logistical movements, transformations, and handovers are recorded on a shared ledger, firms can reconstruct a product's provenance with much greater precision. Such visibility is particularly relevant in sectors where provenance is linked to regulatory compliance or market value, including food safety, pharmaceuticals, and ethically sourced commodities. By consolidating these events into a synchronized ledger, blockchain reduces informational gaps and strengthens the verifiability of sustainability claims (Saber et al., 2018).

Blockchain also enables tamper-resistant audit trails for environmental and social data. Certifications, emissions measurements, due diligence findings, and inspection results can be recorded in an immutable form, creating a durable evidentiary base for sustainability reporting. Because entries cannot be altered retroactively without leaving a detectable trace, blockchain reduces opportunities for data manipulation and enhances the credibility of disclosures submitted under European reporting standards. This immutability is particularly valuable for regulators and certifiers, who can access consistent, time-stamped records rather than relying on self-reported information or periodic audits. As a result, verification processes become more efficient, with reduced administrative burden and greater confidence in the underlying data (World Economic Forum, 2020).

However, blockchain does not automatically ensure full transparency. In most supply chain applications, visibility remains selectively distributed through permissioned networks, where access rights and validation procedures are governed by consortium rules rather than open participation. Moreover, blockchain preserves data integrity after entry, but it does not guarantee that upstream inputs are accurate or complete. Its transparency benefits, therefore, depend on data quality, governance design, and the willingness of supply chain participants to engage in shared information systems.

Another limitation concerns data quality at the point of entry. Although blockchain preserves records in an immutable form, it does not guarantee the accuracy of information provided by upstream actors. Without reliable data collection processes, verification mechanisms, and credible third-party oversight, distributed ledgers risk preserving flawed or misleading information instead of improving sustainability governance (Kouhizadeh et al., 2019). Taken together, blockchain enhances

transparency by strengthening data integrity, increasing information visibility, and supporting more efficient verification processes. However, its effectiveness depends on data quality, the governance design of permissioned networks, and the willingness of supply chain actors to participate in shared information systems. These conditions ultimately determine the extent to which blockchain can meet the evidentiary requirements of European ESG regulation and reduce the information asymmetries that have historically undermined sustainability oversight.

5.3 Mapping Blockchain Capabilities to ESG Pillars

The relationship between blockchain and ESG performance becomes clearer when the technology's core capabilities are mapped onto the environmental, social, and governance dimensions that structure European sustainability regulation. This section translates the conceptual model developed earlier into a structured analysis aligned with the reporting and due-diligence expectations embedded in the CSRD and CSDDD. Across all three pillars, blockchain offers mechanisms that can strengthen data integrity and verification capacity; however, the extent to which these mechanisms translate into substantive ESG outcomes varies significantly across the environmental, social, and governance domains.

5.3.1 Environmental Capabilities

Blockchain can enhance environmental performance primarily by increasing the granularity of emissions and resource-use data. Several pilot projects show that distributed ledgers can record carbon footprints at the level of individual products or shipments, enabling firms to calculate embedded emissions with greater precision. When combined with IoT devices and sensor networks, blockchain can capture real-time environmental metrics such as energy consumption, temperature control in cold chains, or fuel usage in transport.

Similar logic applies in logistics and cold-chain settings, where blockchain can be combined with sensor-generated records of temperature control, transport conditions, and delivery events. In these contexts, the governance value of blockchain lies less in automation alone and more in creating tamper-resistant environmental records that support verification of handling conditions, spoilage reduction, and emissions-related reporting.

Enhanced information visibility also supports green logistics and waste reduction. More reliable chain-of-custody records enable firms to optimize inventory flows, reduce spoilage, and identify inefficiencies in transport routes. These operational improvements align with CSRD requirements for detailed disclosures on resource efficiency, emissions, and environmental impacts across the value chain.

From a regulatory perspective, blockchain's immutability strengthens the auditability of environmental disclosures. CSRD requires companies to provide verifiable, assurance-ready environmental data; blockchain's tamper-resistant logs offer a mechanism for demonstrating the provenance and reliability of such information. However, the extent of realized improvement varies. While some deployments show measurable gains in emissions tracking and waste reduction, others remain limited to pilot phases or face integration challenges with legacy systems.

5.3.2 Social Capabilities

Blockchain's contribution to the social pillar is more complex. The technology can record labor-related certifications and compliance documentation, including fair trade labels, no child labor attestations, and occupational safety audits, in a tamper-resistant format. This creates a more durable record of supplier commitments and can support CSDDD-aligned due diligence processes by documenting social audits across multiple tiers.

Blockchain also facilitates multi-tier monitoring of supplier practices. Because distributed ledgers can capture events beyond the first tier, they provide a mechanism for tracking whether subcontractors comply with required labor standards. This is particularly relevant for CSDDD, which obliges firms to identify and mitigate adverse human-rights impacts throughout their value chains.

Yet significant limitations remain. Social risks are often qualitative, context-specific, and locally embedded conditions that cannot be fully captured through digital records. Blockchain can log the existence of a certification, but it cannot independently verify whether a factory inspection was rigorous, whether workers were interviewed freely, or whether coercive practices were concealed. There is also a risk of superficial compliance logging, where firms upload certificates without addressing underlying labor issues. As a result, blockchain's contribution to the

social pillar should be understood as complementary to, rather than a substitute for, substantive social governance and enforcement mechanisms.

5.3.3 Governance Capabilities

Blockchain's strongest alignment with ESG objectives is in the governance pillar. Distributed ledgers can enhance anti-corruption controls and oversight by recording payments, approvals, and contractual milestones in a tamper-resistant format. This reduces opportunities for unauthorized transactions, retrospective alterations, and selective disclosure, thereby strengthening procurement integrity and internal control systems in global supply chains. Immutable transaction histories also provide a more reliable evidentiary base for boards, auditors, and regulators, supporting CSRD requirements for demonstrable data reliability and verifiable sustainability disclosures. Furthermore, blockchain enhances the credibility of ESG reporting by limiting firms' ability to selectively disclose or conceal information. This is particularly relevant in the European context, where regulators have expressed concern about greenwashing and the opacity of sustainability claims. By providing a secure record of data inputs and verification events, blockchain can help ensure that reported information reflects actual performance rather than narrative framing.

5.3.4 Uneven Effects Across ESG Pillars and Scaling Challenges

Across all three pillars, blockchain offers greater potential to support ESG compliance, particularly in the environmental and governance domains where data structures are more quantifiable and verification needs are clearer. However, the actual impact remains partial and uneven. Many deployments are still in the pilot stage, with limited long-term evidence of sustained improvements. Adoption gaps, interoperability challenges, and regulatory frictions, especially regarding data protection and consortium governance, continue to constrain scalability. In the social domain, blockchain's contribution is inherently limited by the qualitative nature of many labor-related risks.

Overall, blockchain can strengthen the institutional foundations of ESG compliance under CSRD and CSDDD; however, its effectiveness ultimately depends on data quality, network participation, and alignment with broader organizational and regulatory infrastructures rather than on technological adoption alone.

5.4 Limitations, Risks, and Open Issues

Although blockchain offers significant opportunities to enhance oversight and improve the reliability of sustainability-related information, its adoption in European supply chains remains limited by technical, regulatory, organizational, and ESG-specific challenges. A critical assessment of these limitations is essential to avoid deterministic narratives and to situate blockchain within the broader institutional transformations required by the CSRD and CSDDD.

5.4.1 Technical and Economic Constraints

A first set of limitations concerns the technical and economic feasibility of blockchain deployment. Interoperability remains a persistent challenge, as supply chain actors often operate heterogeneous IT systems, and blockchain platforms themselves are fragmented across competing architectures (Kouhizadeh et al., 2019; Treiblmaier, 2018). Scalability presents a related constraint. Even permissioned blockchains can encounter performance bottlenecks when processing large volumes of transactions, particularly in data-intensive sectors. These technical challenges are compounded by significant implementation and maintenance costs, which may discourage small and medium-sized enterprises from participating in blockchain-enabled networks (World Economic Forum, 2020). Consequently, the economic burden of adoption risks reinforcing existing asymmetries between large lead firms and smaller suppliers.

Another practical constraint is the uneven digital maturity of supply chain participants. Blockchain-based systems are often discussed as if all firms can connect to shared infrastructures under similar conditions, but in practice, suppliers differ significantly in data management capacity, IT integration, and readiness to comply with standardized reporting requirements. This heterogeneity is especially important in cross-border supply chains, where smaller firms may still rely on manual documentation, fragmented enterprise systems, or low-cost digital tools that are not easily interoperable with blockchain platforms. Therefore, the technical feasibility of distributed ledgers depends not only on the platform's architecture but also on the broader digital preparedness of the surrounding network.

5.4.2 Regulatory and Legal Tensions

Blockchain also raises regulatory and legal tensions that are particularly significant in the European context. The immutability of distributed ledgers is at odds with the General Data Protection Regulation (GDPR), which grants individuals the right to rectification and erasure of personal data. Finck (2019) and European Commission (2022) note that this tension is structural rather than incidental: immutable ledgers challenge core GDPR principles, and proposed workarounds, such as off-chain storage or hashed identifiers, introduce additional complexity and may undermine the integrity of the ledger. Cross-border data transfer rules further complicate blockchain deployments in global supply chains, especially when nodes are distributed across jurisdictions with differing data protection regimes (Casino et al., 2019). Questions of liability also remain unresolved: if incorrect or fraudulent data are recorded on-chain, responsibility may be ambiguous, creating legal uncertainty for firms relying on blockchain for CSRD- or CSDDD-related disclosures.

Regulatory uncertainty extends beyond data protection in a narrow sense. In the European context, firms must ensure that digital governance systems are not only technically functional but also compatible with evolving expectations for assurance, accountability, and evidentiary reliability. This raises unresolved questions about the legal status of blockchain records in audit and compliance procedures, the admissibility of smart contract-generated actions as evidence of due diligence, and the allocation of responsibility when multiple actors contribute to a shared ledger. Until these issues are clarified, many firms may remain cautious about relying too heavily on blockchain as a primary compliance infrastructure.

5.4.3 Organizational and Political Dynamics

Beyond technical and legal issues, blockchain adoption is influenced by organizational and political dynamics within supply networks. Many firms are reluctant to share operational data due to concerns about competitive advantage, exposure of sensitive information, or reputational risk. Khan et al. (2023) and Karaduman & Gülhas (2025) show that organizational reluctance to share operational data—rooted in concerns about trust, information misuse, and technology governance—remains a significant barrier to blockchain adoption in supply chains, and that the design of permissioned blockchain networks can both

mitigate some of this resistance and introduce new governance challenges related to control, access rights, and stakeholder power dynamics. Lustenberger & Spychiger (2025) and Saberi et al. (2018) argue that these dynamics can undermine the collaborative potential of blockchain and limit the extent to which information visibility is truly distributed across the supply chain.

These organizational dynamics are particularly significant in multi-tier supply chains, where smaller suppliers often lack the technological capabilities, financial resources, or administrative capacity needed to participate in blockchain-enabled reporting systems. While lead firms may see distributed ledgers as tools to improve compliance and visibility, upstream suppliers may regard them as additional reporting burdens with little proportional benefit. This results in an uneven distribution of compliance costs, especially when suppliers are expected to invest in digital infrastructure, data standardization, or staff training to meet the information requirements of dominant buyers. In such contexts, blockchain may reinforce rather than reduce structural asymmetries, as firms with greater bargaining power define the technical architecture, access conditions, and reporting expectations for the broader network.

A related issue concerns the institutional legitimacy of blockchain-based governance arrangements. Even when supply chain actors formally agree to participate in a permissioned consortium, trust in the system is not generated automatically by technology. Participants must also perceive the rules for data access, validation, dispute resolution, and platform oversight as fair and credible. If consortium governance is seen as opaque or disproportionately controlled by a small group of lead firms, other actors may engage only minimally, share data selectively, or treat the platform as a compliance formality rather than a meaningful coordination mechanism. This suggests that the success of blockchain in ESG-oriented supply chain governance depends not only on technical robustness but also on procedurally legitimate governance structures that distribute responsibilities, rights, and incentives in ways perceived as acceptable across the network.

5.4.4 ESG-Specific Risks and Symbolic Adoption

A final set of concerns relates to ESG-specific skepticism. Critics warn that blockchain may be used to signal technological sophistication without addressing underlying governance failures—a phenomenon sometimes described as

“blockchain-washing.” Nikolakis et al. (2018) caution that blockchain can entrench superficial certification practices by recording the existence of labels or audits without ensuring their substantive quality. LeBaron & Lister (2021) similarly show that certification systems often mask underlying labor issues, suggesting that blockchain may digitize rather than resolve these structural weaknesses. ESMA (2024) further warns that unverifiable sustainability claims remain a systemic risk, even when supported by digital tools. Without robust verification processes, blockchain risks becoming a technologically sophisticated repository for flawed information rather than a mechanism for improving sustainability governance.

This risk is particularly relevant in regulatory environments where firms face increasing pressure to demonstrate visible compliance with sustainability standards. In such contexts, blockchain may be adopted not because it transforms underlying governance practices, but because it offers a convincing appearance of control, innovation, and traceability. The symbolic value of blockchain can thus become disconnected from substantive improvements in environmental or social performance. In this sense, the danger is not only technological overstatement but also institutional complacency: once digital traceability tools are implemented, firms and external stakeholders may overestimate the extent to which underlying risks have actually been reduced.

5.4.5 Integrated Assessment

Taken together, these limitations show that blockchain should be understood as a contingent governance instrument rather than a self-sufficient compliance solution. Its value lies in improving traceability, auditability, and procedural consistency, but these benefits depend on regulatory alignment, interoperable infrastructure, organizational cooperation, and credible data-generating practices across the supply chain.

From this perspective, the central issue is not whether blockchain can contribute to ESG governance, but under what conditions such contributions become credible, scalable, and institutionally meaningful. Its value is likely greatest where verification demands are high, data points are relatively codifiable, and participating actors share sufficient incentives to maintain common standards. In contrast, in fragmented supply chains marked by weak trust, uneven digital capabilities, and ambiguous

accountability, blockchain may add complexity without resolving the underlying governance deficit. A balanced assessment therefore requires attention not only to technological potential, but also to the institutional fit between blockchain architectures and the broader regulatory and organizational environments in which they operate.

6 Conclusion and Implications

6.1 Direct Answer to the Research Question

This paper examines how blockchain reshapes governance and information visibility in European supply chains and to what extent these changes enhance ESG performance under the CSRD and CSDDD. The analysis demonstrates that blockchain introduces a measurable shift towards more data-driven, traceable, and auditable governance structures, replacing fragmented documentation systems and periodic inspections with continuous, tamper-resistant information flows. These changes strengthen firms' ability to monitor upstream activities, verify sustainability claims, and maintain reliable audit trails. However, these governance transformations occur predominantly within permissioned blockchain consortia, where access rights, validation rules, and data visibility remain subject to consortium-level control. As a result, blockchain reconfigures rather than eliminates existing power asymmetries, and transparency remains selectively distributed rather than universal.

Regarding ESG enhancement, the findings suggest that blockchain is most useful in the environmental and governance pillars, where verification needs are clearer and data structures are more easily codified. It can improve emissions tracking, documentation reliability, and the auditability of due diligence processes, thereby supporting the evidentiary requirements of the CSRD and CSDDD. However, its contribution remains partial: social risks are often less amenable to digital codification, and implementation outcomes continue to vary across sectors and organizational settings. Blockchain, therefore, strengthens the institutional foundations of ESG compliance but does not replace broader governance, enforcement, or supplier engagement mechanisms.

6.2 Implications for Policymakers, Companies, and Researchers

The findings of this study have several implications for the key actors shaping the future of ESG-aligned supply chain governance in Europe. For policymakers, the analysis highlights that regulatory ambition increasingly depends on data infrastructures that support it. The analysis also underscores the need for clearer institutional guidance on integrating blockchain into the CSRD and CSDDD compliance landscape. Interoperability standards remain underdeveloped, and without common technical protocols, blockchain networks risk fragmentation and incompatibility. Regulators may therefore need to promote standardized data models, shared taxonomies, and certification frameworks that enable cross-platform communication. In addition, the persistent tension between blockchain's immutability and the GDPR suggests a need for regulatory clarification or interpretive guidance to help firms navigate data protection obligations when using distributed ledgers. Policymakers may also consider incentives for responsible data sharing, particularly in sectors where supply chain opacity has historically undermined sustainability oversight.

For companies, blockchain adoption requires strategic decision-making rather than technological enthusiasm. Firms must assess where blockchain meaningfully improves oversight, such as emissions tracking, auditability, or multi-tier supplier monitoring, and where alternative digital tools may be more appropriate. Effective implementation also depends on collaboration across supply chain partners, as blockchain's value emerges only when a critical mass of actors participates in the network. This means that firms must invest not only in technology but also in supplier engagement, capacity building, and data quality assurance. The analysis further highlights the importance of addressing governance questions within permissioned consortia, including node control, access rights, and decision-making procedures, to avoid reproducing existing power asymmetries.

For researchers, the study identifies several avenues for future inquiry. Much of the existing evidence on blockchain's ESG impact is conceptual or based on early-stage pilots. There is a clear need for empirical, longitudinal research examining how blockchain performs in mature deployments, particularly within European regulatory contexts. Comparative studies evaluating blockchain alongside other digital technologies, such as IoT systems, cloud-based traceability platforms, or

AI-enabled risk analytics, would also help clarify where blockchain offers distinctive advantages. Finally, more work is needed on the social dimension of ESG, where blockchain's contributions remain limited and where qualitative, context-specific risks challenge the assumptions of digital traceability.

6.3 Limitations of the Study

The contributions of this paper must be interpreted in light of several methodological limitations. First, the analysis is conceptual and literature-based, relying on secondary sources rather than primary empirical data. While this approach is suitable for synthesizing emerging insights across technology, governance, and regulation, it limits the ability to assess how blockchain performs in fully operational, large-scale European supply chain settings. Many of the cases referenced in the literature remain pilot projects or early-stage deployments, and the evidence base is therefore uneven across sectors and ESG dimensions.

Second, the study draws primarily on published and publicly documented cases, which may overrepresent successful or well-publicized implementations while underrepresenting failed, abandoned, or commercially sensitive projects. This introduces a degree of publication bias that cannot be fully eliminated. Third, the analysis focuses on the European regulatory environment, particularly the CSRD and CSDDD. While this provides a coherent institutional framework, it also means that findings may not be directly generalizable to jurisdictions with different regulatory architectures, data-protection regimes, or supply chain structures.

Finally, mapping blockchain capabilities to ESG pillars necessarily simplifies the complexity of real-world sustainability challenges. Environmental and governance metrics are more amenable to digital traceability than many social issues, which are qualitative, context-specific, and resistant to codification. Therefore, the conclusions should be interpreted as analytically indicative rather than empirically definitive, especially regarding large-scale operational performance and the social dimensions of ESG.

6.4 Final Reflection

Taken together, the findings of this study suggest that blockchain represents a meaningful, though not definitive, step towards more accountable and transparent supply chain governance in Europe. The technology's capacity to generate tamper-resistant audit trails, support continuous monitoring, and strengthen the evidentiary basis of sustainability disclosures aligns closely with the institutional demands introduced by the CSRD and CSDDD. Yet blockchain's impact is neither automatic nor universal. Its effectiveness depends on the quality of underlying data, the governance structures of permissioned networks, and the willingness of firms to collaborate across organizational and competitive boundaries. These conditions highlight that blockchain is best understood not as a standalone solution but as one component within a broader socio-technical system that includes regulatory frameworks, organizational practices, and human judgement.

The broader implication is that technological innovation alone is insufficient to resolve the structural challenges of sustainability governance. Blockchain can enhance visibility, reduce information asymmetries, and support more credible reporting, but it cannot substitute for robust due diligence processes, meaningful supplier engagement, or strong regulatory enforcement. As European supply chains adapt to increasingly stringent ESG expectations, blockchain may serve as valuable enabling infrastructure, improving the reliability of sustainability information and supporting more consistent oversight. Its long-term contribution, however, will depend on how effectively it is integrated into the institutional, organizational, and social arrangements that underpin responsible business conduct.

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SOCIO-ECONOMIC EFFECTS OF DEMOLISHING SQUATTER SETTLEMENTS IN NOORPUR SHAHAN, ISLAMABAD: AN ESG PERSPECTIVE

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This study investigates the socio-economic consequences of demolishing squatter settlements in Noorpur Shahan (originally Chorpur), Islamabad, through an Environmental, Social, and Governance (ESG) lens. Using primary qualitative methods, including field visits, structured interviews with affected residents, and direct observations, the research highlights how forced evictions disrupt livelihoods, income, social networks, and psychological well-being. Despite limited environmental or governance benefits, the demolitions reflect gaps in policy planning and a neglect of social considerations. The findings emphasize the need for inclusive resettlement strategies, social protection measures, and community engagement in urban development policies to mitigate adverse impacts on marginalized populations.

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1 Introduction

Noorpur Shahan, originally known as Chorpur, is located at the foothills of the Margalla Hills in Islamabad, Pakistan. Islamabad, established in 1967 as a planned capital city, involved the acquisition of approximately 45,000 acres of land from surrounding rural settlements. This process of planned urban development, as highlighted in urban transition theories (Davis, 2006; UN-Habitat, 2020), often generates informal settlements due to displacement, inadequate compensation mechanisms, and rural urban migration pressures. In this context, informal settlements in Noorpur Shahan can be understood as a structural outcome of uneven urbanization rather than merely unauthorized land occupation. These settlements, including Muslim Colony, Narrola Village, Mohallah Tehjar, Balti Mohallah, and Nori Bagh, are inhabited by both indigenous populations who lived there before the establishment of Islamabad and migrants who arrived due to economic necessity.

The Capital Development Authority (CDA), responsible for urban planning and land management in Islamabad, has periodically undertaken demolition operations targeting informal settlements. Existing literature on forced evictions (e.g., Fernandes, 2011; Human Rights Watch, 2025) conceptualizes such actions as governance instruments often employed in cities undergoing rapid spatial restructuring, where regulatory enforcement tends to prioritize land formalization over social protection. In Noorpur Shahan, demolition practices have reportedly involved limited formal notification procedures and have resulted in the removal of residential, commercial, and educational structures. Rather than framing these actions normatively, this study approaches them analytically as policy interventions with measurable socio-economic consequences.

Forced evictions, as shown in Figure 1, are defined by the United Nations Committee on Economic, Social, and Cultural Rights (1997) as the removal of individuals or communities from their homes without adequate legal safeguards. The theoretical framing of forced evictions intersects with rights based approaches to urban development and the concept of “the right to the city” (Lefebvre, 1968; further operationalized in UN-Habitat frameworks), which emphasize equitable access to urban space and services. These frameworks provide a conceptual basis for examining how eviction practices affect access to housing, livelihoods, and social infrastructure. In Pakistan, constitutional provisions such as Article 38 outline the

state's responsibility to ensure basic welfare. International instruments, including the Universal Declaration of Human Rights and the International Covenant on Economic, Social and Cultural Rights, establish broader normative benchmarks.



Figure 1: Residents of Noorpur Shahan Displaced Due to Forced Evictions
Source: Photograph taken by the author (2026)

From an Environmental, Social, and Governance (ESG) perspective, the demolition of informal settlements presents a multidimensional policy issue. ESG theory, increasingly applied in urban governance research (Kuffer et al., 2016; UN-Habitat, 2020), provides an integrated framework to evaluate policy impacts across environmental sustainability, social equity, and institutional accountability. In the case of Noorpur Shahan, preliminary observations suggest that environmental gains from land clearance are limited, while social disruptions and governance challenges are more pronounced. This study therefore situates the case within ESG oriented urban governance literature. It aims to empirically assess how demolition practices align or fail to align with ESG principles.

Importantly, this research addresses a gap in the existing literature by offering a localized, qualitative case study of demolition induced socio-economic impacts in Islamabad, with explicit linkage to ESG analytical frameworks. While prior studies have examined informal settlements at global or national levels, fewer have provided site specific, empirically grounded analyses integrating social and governance dimensions. Accordingly, the objective of this study is not to generalize across all urban contexts but to generate context sensitive insights into the socio-economic

effects of demolition in Noorpur Shahan, thereby contributing to more evidence based and inclusive urban policy discussions.

2 Literature Review

Informal settlements, commonly referred to as squatter settlements, slums, or unplanned residential areas, represent a significant dimension of contemporary urbanization, affecting over 1.1 billion people globally (UN-Habitat, 2020). Recent scholarship frames the emergence of such settlements within broader theoretical constructs of rapid urbanization, structural inequality, and governance deficits (Davis, 2006; UN-Habitat, 2020). Rather than being anomalies, informal settlements are increasingly understood as integral components of urban systems, shaped by land market exclusion, migration dynamics, and institutional limitations. In developing countries, including Pakistan, these settlements often provide affordable housing solutions for low income populations but remain characterized by insecure tenure, inadequate infrastructure, and heightened exposure to environmental and socio-economic risks.

The literature on forced evictions has evolved from descriptive accounts to more theoretically grounded analyses incorporating human rights, urban governance, and political economy perspectives. Fernandes (2011) emphasizes that eviction practices in developing urban contexts frequently reflect top down regulatory frameworks that lack participatory planning mechanisms. Similarly, Human Rights Watch (2025) documents how forced evictions in Pakistan disproportionately affect marginalized populations, often exacerbating poverty and social exclusion. These studies highlight that eviction is not merely a spatial intervention but a socio-political process with multidimensional impacts.

From a socio-economic standpoint, forced evictions have been consistently associated with loss of livelihoods, income instability, and disruption of social networks. Empirical studies indicate that informal economies, which are often embedded within residential spaces, are particularly vulnerable to demolition policies, resulting in immediate and long-term income shocks (Davis, 2006). Furthermore, research demonstrates that displacement weakens social capital by fragmenting community networks that function as informal safety nets, thereby reducing resilience among affected populations. Vulnerable groups, including

women, children, the elderly, and persons with disabilities, are disproportionately impacted, experiencing heightened psychological stress and reduced access to essential services such as education and healthcare.

Recent contributions have also emphasized the psychological and educational dimensions of displacement, which have historically received less attention. Studies show that forced evictions disrupt children's educational continuity and contribute to emotional distress, thereby affecting long term human capital development. This aligns with broader development theories that link stable housing conditions to social well-being and intergenerational mobility.

From an Environmental, Social, and Governance (ESG) perspective, the literature underscores the need for integrated policy evaluation frameworks. Kuffer, Pfeffer, and Sliuzas (2016) highlight that while environmental arguments, such as land reclamation and improved urban aesthetics, are often used to justify demolition, the actual ecological benefits tend to be limited when not accompanied by structured redevelopment plans. In contrast, the social (S) and governance (G) dimensions of ESG frequently reveal significant deficits, particularly in terms of inadequate resettlement planning, lack of stakeholder engagement, and weak institutional accountability. ESG oriented analyses therefore provide a more holistic lens for assessing the trade-offs inherent in urban demolition policies.

Governance related scholarship further identifies institutional fragmentation, corruption, and regulatory inconsistencies as key drivers of informal settlement proliferation and subsequent eviction cycles. In the context of Islamabad, the persistence of informal settlements has been linked to administrative lapses, including unauthorized approvals and weak enforcement of land use regulations. This creates a paradox in which state institutions both enable and later penalize informality, raising critical questions about policy coherence and accountability.

International legal and normative frameworks play a central role in shaping the discourse on forced evictions. The United Nations' Basic Principles and Guidelines on Development Based Evictions establish that evictions should only occur under conditions of due process, adequate notice, and provision of alternative housing. Similarly, the International Covenant on Economic, Social and Cultural Rights (Article 11) recognizes the right to adequate housing as a fundamental human right.

These frameworks are complemented by the “right to the city” concept, which advocates inclusive and participatory urban governance. The literature suggests that non-compliance with these principles often results in adverse socio-economic outcomes and increased urban inequality.

Despite the breadth of global and regional studies, a critical gap remains in context specific, empirically grounded analyses that integrate ESG dimensions within localized urban settings such as Islamabad. Existing research has largely focused on macro level trends or single dimensional analyses (e.g., environmental or economic impacts), with limited attention to the intersection of social vulnerability and governance practices at the community level.

This study contributes to the literature by providing a qualitative, site specific examination of the socio-economic impacts of demolition in Noorpur Shahan, explicitly linking empirical findings to ESG theoretical frameworks and urban governance debates. In doing so, it advances a more nuanced understanding of how demolition policies affect marginalized populations and highlights the importance of integrating social equity and institutional accountability into urban development strategies.

3 Methodology

3.1 Research Design

This study adopts a qualitative case study design to examine the socio-economic impacts of demolishing squatter settlements in Noorpur Shahan, Islamabad, through an Environmental, Social, and Governance (ESG) framework. The qualitative approach is theoretically grounded in Interpretivist research paradigms, which emphasize understanding lived experiences, social meanings, and institutional practices in context-specific settings (Creswell, 2014). This design is particularly appropriate for exploring complex phenomena such as forced evictions, where quantitative indicators alone may not capture the depth of socio-economic and psychological impacts.

The case study strategy was selected to enable an in-depth, context sensitive investigation of demolition practices in a specific geographic and institutional setting. Rather than aiming for statistical generalization, the study seeks analytical generalization by linking empirical observations to ESG theory and urban governance frameworks.

3.2 Study Area

The study area comprises multiple informal settlement clusters, including Muslim Colony, Narrola Village, Mohallah Tehjar, Balti Mohallah, and Nori Bagh, as illustrated in Figure 2. These areas were selected due to their direct exposure to recent demolition activities carried out by the Capital Development Authority (CDA), making them relevant sites for examining the immediate and short term impacts of forced evictions.

The spatial selection of the study area follows purposive case selection logic, focusing on locations where the phenomenon of interest (demolition of informal settlements) is most pronounced. This enhances the explanatory depth of the research while maintaining alignment with qualitative research standards.



Figure 2: Scattered Concrete Block Debris Across Demolition Sites
Source: Photograph taken by the author (2026)

3.3 Data Collection Methods

Primary data were collected through a combination of field visits, structured interviews, and direct observation. To improve methodological transparency, the data collection process was conducted in three sequential phases: (i) preliminary field reconnaissance, (ii) structured interview administration, and (iii) observational validation.

- (i) **Field Visits:** Multiple site visits were conducted to document the physical extent of demolitions, including residential structures, commercial shops, and educational facilities. These visits enabled real-time observation of displacement patterns and coping strategies adopted by affected residents.
- (ii) **Structured Interviews:** A total of approximately 50 structured interviews were conducted using a predefined interview guide to ensure consistency across respondents. The interview instrument consisted of four thematic sections: (a) household socio-economic profile, (b) income and livelihood impacts, (c) housing and displacement experiences, and (d) perceptions of governance and institutional response. Each interview included both closed-ended and open-ended questions, allowing for comparability while also capturing detailed narratives.
- (iii) **Direct Observation:** Observational data were systematically recorded to complement interview findings. An observation checklist was used to document indicators such as housing damage, availability of basic services, presence of debris, and informal reconstruction activities. This triangulation of data sources enhances the reliability and validity of the findings.

Interviews were conducted in Urdu language, and responses were later translated into English for analysis. This approach ensured inclusivity and minimized language barriers during data collection.

3.4 Sampling Strategy and Sample Description

A purposive sampling technique was employed to select participants who had been directly affected by demolition activities. The sampling criteria included: (i) households experiencing residential or commercial loss, (ii) presence of vulnerable

members (e.g., children, elderly, disabled individuals), and (iii) representation from different settlement clusters within Noorpur Shahan.

The sample comprised approximately 50 households distributed across Muslim Colony, Balti Mohallah, Nori Bagh, and adjacent areas. Within each household, the primary respondent was typically the head of the household; however, additional perspectives were obtained from elderly residents and school age children where relevant. This approach allowed for capturing intra-household variations in socio-economic impact.

While the study ensured diversity in socio-economic representation, it is important to note that the sample is not statistically representative of the entire population. Instead, it is analytically representative, consistent with qualitative research objectives.

3.5 Methods of Analysis

Data were analyzed using thematic content analysis. The analytical process followed a systematic coding procedure consisting of three stages: (i) open coding to identify initial categories, (ii) axial coding to establish relationships between categories, and (iii) selective coding to align findings with ESG dimensions.

The identified themes were categorized according to ESG criteria:

Environmental (E): Land use changes, infrastructure destruction, and environmental inefficiencies.

Social (S): Income loss, housing instability, educational disruption, psychological stress, and breakdown of social networks.

Governance (G): Institutional practices, eviction procedures, legal compliance, and administrative accountability.

To strengthen analytical rigor, empirical findings were iteratively compared with existing literature, enabling the identification of convergences and divergences between local observations and broader theoretical frameworks.

The study also developed a mathematical formula to estimate socio-economic loss due to demolitions:

$$SEL = \sum_{i=1}^n (H_i \times L_i + S_i \times E_i) \quad (1)$$

Where:

SEL = Socio-Economic Loss

H_i = Number of households affected

L_i = Average income loss per household

S_i = Number of schools or shops demolished

E_i = Estimated economic value of destroyed infrastructure

3.6 Ethical Considerations

The study adheres to established ethical research standards, including informed consent, voluntary participation, and confidentiality. Participants were informed about the purpose of the study and their right to withdraw at any stage. Special care was taken when engaging with vulnerable groups, ensuring that interviews were conducted sensitively and without causing additional psychological distress.

4 Research Results

4.1 Socio-Economic Disruptions

The findings indicate that demolition activities in Noorpur Shahan and Nareel Village resulted in substantial socio-economic disruptions across affected households. Empirical evidence from structured interviews shows that a majority of respondents experienced immediate income loss due to the destruction of commercial shops and home based enterprises. This finding is consistent with existing literature (Davis, 2006), which highlights the vulnerability of informal economies embedded within residential spaces.

Approximately 70–80% of interviewed households reported partial or complete loss of income sources, particularly those dependent on small retail shops, daily wage labor, or home based services. Respondents indicated that these income losses were

not temporary but had ongoing effects due to the absence of alternative livelihood opportunities. In addition, low profile government employees who had invested in informal housing as a supplementary economic asset also reported financial setbacks.

Housing instability emerged as a critical consequence of demolition. Interview data reveal that displaced households adopted multiple coping strategies, including temporary relocation to nearby areas such as Bara Kahu, return migration to native regions, and informal reconstruction in adjacent localities. These adaptive responses, while necessary, often resulted in increased financial burden and social dislocation. A notable secondary effect was the increase in rental prices in nearby settlements, attributed by respondents to sudden population influx.

4.2 Educational Disruption

The demolition of private schools located within informal settlements had direct implications for children's access to education, as illustrated in Figure 3.



Figure 3: Demolished School Building
Source: Photograph taken by the author (2026)

Field observations and interview responses confirm that multiple low-cost private educational facilities were either partially or fully destroyed, leading to immediate discontinuation of schooling for enrolled students.

Parents reported that children faced uncertainty regarding school re-enrolment, financial constraints in accessing alternative institutions, and psychological distress associated with the abrupt loss of familiar learning environments. Approximately 60% of interviewed households with school age children indicated that their children's education was interrupted for at least several weeks following the demolitions.

These findings align with prior research emphasizing the linkage between housing stability and educational continuity, reinforcing the argument that eviction induced displacement has long-term implications for human capital development.

4.3 Psychological and Social Stress

The study identifies significant psychological and social impacts associated with forced evictions. A majority of respondents reported experiencing stress, anxiety, and uncertainty related to housing insecurity and income loss. These effects were particularly pronounced among vulnerable groups, including elderly individuals, persons with disabilities, and households with young children.

Qualitative narratives indicate that the anticipation of eviction, combined with inadequate notice procedures, contributed to prolonged psychological distress even before the actual demolition occurred. Parents expressed concern regarding their children's emotional well-being, while elderly respondents reported feelings of helplessness and social isolation.

In addition to individual stress, the disruption of community networks was identified as a key social consequence. Informal settlements often function as support systems providing financial, emotional, and logistical assistance. The fragmentation of these networks reduced collective resilience and coping capacity, corroborating findings from Fernandes (2011).

4.4 Governance Practices and Institutional Response

The results highlight several governance related issues associated with the demolition process. Interview data suggest that notification procedures were largely informal, with many respondents reporting verbal announcements or loudspeaker

warnings rather than written legal court notices. This indicates procedural inconsistencies in the implementation of eviction policies.

Notably, a medical doctor was appointed as Deputy Director General (Enforcement) to oversee demolition operations, despite lacking formal training in urban engineering or land-use planning. This appointment violates Article 18 of the Constitution of Pakistan and exemplifies misaligned governance practices.

CDA's justification of compensating indigenous residents raises further questions. If compensation was indeed disbursed after Islamabad's establishment, why was the land not vacated at the time? Moreover, no meaningful action was taken against officials who accepted bribes for the construction of informal housing, indicating systemic corruption and regulatory failure.

The institutional response was also characterized by a strong enforcement presence, with law enforcement personnel accompanying demolition teams, as illustrated in Figure 4. While this ensured operational execution, it also contributed to perceptions of coercion among affected residents.



Figure 4: CDA's Employees Operating Under Police Presence

Source: Photograph taken by the author (2026)

These findings suggest gaps in governance practices, particularly in relation to transparency, procedural fairness, and alignment with established legal and policy frameworks.

4.5 Environmental Implications

The environmental outcomes of demolition activities were found to be limited and, in some cases, counterproductive. Field observations indicate that while land clearance was achieved, there was no immediate evidence of planned redevelopment or environmental restoration. Instead, demolished areas were characterized by debris accumulation and underutilized land.

Additionally, the destruction of existing infrastructure, such as electricity connections and paved roads, represents a loss of previously invested public resources. This finding challenges the assumption that demolition inherently contributes to environmental improvement as suggested in some policy narratives.

From an ESG perspective, the environmental dimension appears to be weakly realized in the absence of integrated planning and redevelopment strategies.

4.6 Legal and Human Rights Violations

The findings also reveal significant concerns related to legal compliance and right based protections. Respondents' accounts suggest that eviction processes did not consistently adhere to formal legal procedures, particularly regarding advance notice, documentation, and provision of alternative housing options.

While this study does not provide a legal adjudication, the empirical evidence indicates potential misalignment between observed practices and established national and international frameworks governing forced evictions. These include constitutional provisions related to welfare and international guidelines emphasizing due process and protection of vulnerable populations.

4.7 Socio-Economic Loss Estimation

Using the formula presented in Section 3, socio-economic loss (SEL) can be approximated. For example, with 500 households affected (H_i), average monthly income loss of PKR 20,000 per household (L_i), and 20 demolished schools/shops with estimated economic value PKR 15 million each ($S_i \times E_i$), the cumulative SEL is:

$$SEL = \sum_{i=1}^{500} (H_i \times L_i + S_i \times E_i) = (500 \times 20,000) + (20 \times 15,000,000) = 10,000,000 + 300,000,000 = 310,000,000 \text{ PKR} = 310 \text{ million PKR} = \text{Approximate value } 1.11 \text{ million USD}$$

This quantification underscores the substantial financial, social, and human costs of top-down demolition practices.

5 Discussion

The findings of this study provide a context-specific understanding of the socio-economic and governance implications of demolishing informal settlements in Noorpur Shahan, Islamabad. When interpreted through an Environmental, Social, and Governance (ESG) framework, the results reveal a clear imbalance among the three dimensions, with social and governance costs significantly outweighing any observable environmental benefits. This section analytically situates the empirical findings within existing literature and theoretical frameworks, avoiding overgeneralization while highlighting key patterns relevant to similar urban contexts.

5.1 ESG Based Analytical Interpretation

Environmental Dimension (E):

The empirical results suggest that environmental gains from demolition activities are limited in the absence of planned redevelopment. While land clearance is often justified as a means of improving urban environmental quality, the observed accumulation of debris and underutilized land indicates that demolition alone does not constitute effective environmental management. This finding is consistent with Kuffer et al. (2016), who argue that environmental benefits of slum clearance are contingent upon integrated urban planning and post demolition land use strategies.

Additionally, the destruction of existing infrastructure, such as electricity networks and paved roads, represents a reversal of prior development investments and thereby reduces overall resource efficiency. From an ESG perspective, this reflects a weak alignment with environmental sustainability principles.

Social Dimension (S):

The study identifies extensive social impacts, including income loss, housing instability, educational disruption, and psychological stress. These findings strongly align with prior research (Davis, 2006; Fernandes, 2011), which emphasizes that forced evictions disproportionately affect economically vulnerable populations and undermine informal support systems.

Importantly, the results highlight the interconnected nature of socio-economic variables. For instance, loss of housing directly contributed to educational discontinuity and psychological distress, demonstrating that eviction impacts are multidimensional rather than isolated. This supports theoretical perspectives that view housing as a central determinant of social well-being and human development.

The observed increase in rental prices in nearby areas such as Bara Kahu further illustrates the secondary effects of displacement, reinforcing the argument that eviction policies can generate broader urban inequalities beyond the immediate area of intervention.

Governance Dimension (G):

Governance related findings reveal procedural inconsistencies and institutional gaps in the implementation of demolition policies. The reliance on informal notification methods, absence of structured resettlement planning, and lack of transparent compensation mechanisms indicate deviations from established governance standards and international guidelines on forced evictions.

These observations are consistent with governance literature in the Pakistani context, which identifies institutional fragmentation and regulatory inconsistencies as key challenges in urban management. Furthermore, the findings illustrate a policy paradox: state institutions that historically enabled informal settlement expansion through weak enforcement later adopt coercive measures to eliminate these settlements, raising questions about accountability and policy coherence.

5.2 Comparison with Existing Literature

The empirical findings of this study both corroborate and extend existing literature on informal settlements and forced evictions. Consistent with global studies, the results confirm that demolition led interventions often produce significant socio-economic disruptions while failing to achieve sustainable environmental outcomes.

However, this study contributes additional insights by explicitly integrating ESG analysis at a localized level. Unlike many macro level studies, the findings demonstrate how ESG dimensions interact within a specific urban context, revealing that governance deficiencies often amplify social vulnerabilities.

Moreover, the identification of secondary effects, such as increased rental pressures in adjacent settlements, adds to the literature by illustrating the spatial diffusion of eviction impacts, an area that has received relatively limited empirical attention.

5.3 Implications for Urban Governance and Policy

The discussion highlights several implications for urban governance. First, the findings suggest that demolition-based approaches, when implemented without comprehensive planning, may exacerbate rather than resolve urban challenges. This underscores the need for policy frameworks that integrate social protection, stakeholder engagement, and long-term planning.

Second, the study reinforces the relevance of ESG frameworks as analytical tools for evaluating urban policies. By systematically assessing environmental, social, and governance outcomes, policymakers can better identify trade-offs and design more balanced interventions.

Third, the results indicate the importance of data-driven planning mechanisms. The proposed use of technologies such as UAV (Unmanned Aerial Vehicle) based surveys, while not implemented in this study, aligns with emerging trends in urban analytics and could support more accurate assessment of population needs, infrastructure requirements, and risk factors in seismic zones.

5.4 Study Specific Scope and Analytical Boundaries

It is important to emphasize that the findings of this study are based on a qualitative case study of Noorpur Shahan and should be interpreted within this specific context. While the results share similarities with broader urban trends, they do not aim to provide universal generalizations.

The study focuses primarily on short term and immediate impacts of demolition, and therefore does not capture long term adaptation strategies or policy outcomes. Additionally, the qualitative nature of the research prioritizes depth of understanding over statistical representativeness.

6 Conclusions

- (i) The present study examined the socio-economic effects of demolishing squatter settlements in Noorpur Shahan, Islamabad, using an Environmental, Social, and Governance (ESG) analytical framework. Based on qualitative evidence derived from field observations and structured interviews, the findings indicate that demolition practices are associated with significant socio-economic disruption, while delivering limited observable environmental benefits within the studied context.
- (ii) The study demonstrates that affected households experienced income loss, housing instability, educational interruption, and psychological stress. These impacts were particularly pronounced among vulnerable groups, including children, elderly individuals, and low income households. The results further indicate that displacement effects extended beyond the immediate area, contributing to increased rental pressures and social strain in nearby localities.
- (iii) From an ESG perspective, the findings suggest an imbalance among the three dimensions. The environmental component appears weakly realized due to the absence of coordinated redevelopment and resource optimization. In contrast, the social dimension reflects substantial adverse impacts on livelihoods and well-being, while the governance dimension reveals procedural inconsistencies, including limited transparency in notification processes and the absence of structured resettlement mechanisms.
- (iv) Importantly, the conclusions of this study are confined to the scope of a qualitative case study and should be interpreted accordingly. The research

does not seek to generalize across all urban settings but instead provides context specific insights into the dynamics of demolition-led interventions in Noorpur Shahan.

- (v) The study contributes to the existing body of knowledge by integrating ESG theory with empirical analysis at a localized level. It highlights the importance of aligning urban policy interventions with principles of social equity, institutional accountability, and environmental sustainability.
- (vi) Future research may build on these findings by incorporating longitudinal designs, quantitative validation, and comparative analyses across different urban contexts. Such approaches would enable a more comprehensive assessment of long term impacts and policy effectiveness.
- (vii) Overall, the study underscores that demolition based urban interventions, when implemented without inclusive planning and governance safeguards, may generate substantial socio-economic costs. A more balanced and evidence-based approach to urban development grounded in ESG principles remains essential for addressing the challenges associated with informal settlements in Islamabad and comparable urban environments.

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Kamran Khan (born February 2, 1973) is a Pakistani interdisciplinary research engineer distinguished for substantive contributions spanning scientific, engineering, and economic disciplines. He earned a Master of Science in Mechanical Engineering from Zaporozhye State Technical University, Ukraine, in 1998. Throughout his career, he has authored and presented over seventy peer reviewed papers at international conferences across Azerbaijan, Belarus, Bosnia and Herzegovina, Estonia, Georgia, Kazakhstan, Latvia, Lithuania, Moldova, the Russian Federation, Slovenia, Turkmenistan, and Ukraine, with all studies published in indexed proceedings. Currently affiliated with Pakneftegaz in Islamabad, he advances integrative, high impact research that synthesizes rigorous theoretical modelling and empirical modelling with applied, multidisciplinary methodologies. His scholarly record, indexed under ORCID 0000-0002-2470-1296, reflects sustained international collaboration, methodological sophistication, and interdisciplinary breadth, shaping policy discourse, industrial standards, and global innovation.

AN EMPIRICAL STUDY OF MICROSOFT COPILOT ADOPTION IN FINANCIAL TECHNOLOGY: PRODUCTIVITY, PERFORMANCE, AND TRUST PERSPECTIVES

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This chapter presents an empirical study examining the determinants of Microsoft Copilot usage among software development professionals in the FinTech sector. Drawing on technology acceptance and socio-technical perspectives, the study investigates how perceived productivity, performance enhancement, learning and development, trust, and sectoral impact influence actual usage behavior. Data were collected from 154 developers through a structured survey and analyzed using non-parametric statistical methods. The findings indicate that usage frequency and application domain significantly shape general usage and learning perceptions, while gender differences emerge in the trust dimension; education level and professional experience show no statistically significant effects. Overall, the results highlight that contextual engagement, and practical performance benefits play a more decisive role in AI-assisted tool adoption than demographic characteristics, offering implications for structured and domain-specific implementation strategies in regulated software environments.

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1 Introduction

The rapid development of artificial intelligence technologies has significantly influenced the field of software engineering. AI-supported coding assistants have become increasingly integrated into development environments, offering real-time suggestions, automated code generation, debugging support, and optimization recommendations. Among these tools, Microsoft Copilot has emerged as one of the most widely adopted AI-based assistants designed to enhance software development processes.

Unlike traditional development tools, AI-powered assistants do not merely provide static functionalities; instead, they actively interact with developers, support decision-making processes, and contribute to productivity and code quality improvements. As organizations strive to accelerate development cycles and improve efficiency, AI-supported tools are increasingly positioned as strategic assets within software teams. However, the actual usage of such tools is not determined solely by their technical capabilities. Developers' perceptions regarding productivity, performance improvement, learning opportunities, trust, and broader sectoral impact play a crucial role in shaping adoption behavior.

While existing research largely focuses on the technical performance of AI-based systems, fewer studies examine the behavioral and perceptual factors that influence developers' actual usage of AI coding assistants. Understanding these determinants is essential for both academic research and practical implementation strategies, as effective adoption depends not only on availability but also on user acceptance and perceived value.

In this context, the present study aims to identify the key factors influencing Microsoft Copilot usage among software development professionals. Specifically, the study examines the effects of perceived productivity, performance enhancement, learning and development, trust and criticism, and sectoral impact on actual Copilot usage behavior. By empirically analyzing these relationships, this research seeks to contribute to the growing literature on AI-assisted software development and to provide insights into the behavioral dynamics underlying AI tool adoption.

2 Literature Review

AI-assisted software development tools, particularly GitHub Copilot, have significantly transformed contemporary software engineering practices. These systems are built upon large-scale transformer architectures (Vaswani et al., 2017) and large language models capable of few-shot learning (Brown et al., 2020). Leveraging OpenAI Codex (OpenAI, 2021; Chen et al., 2021), Copilot generates context-aware code suggestions based on natural language prompts, representing a shift from rule-based automation to probabilistic generative assistance embedded within development environments.

From a theoretical perspective, the adoption of such tools can be explained through the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), where perceived usefulness and ease of use are key determinants of behavioral intention. In high-pressure and regulated domains such as FinTech, these factors become even more critical.

Empirical studies consistently demonstrate that Copilot enhances developer productivity. Peng et al. (2023) report that developers complete tasks significantly faster when using AI assistance, while industry findings (GitHub Blog, 2024) confirm improvements in development speed and workflow efficiency. These findings align with diffusion theory (Rogers, 2003), suggesting that repeated exposure reinforces sustained adoption.

However, productivity gains are accompanied by important concerns. Research shows that AI-generated code may contain security vulnerabilities (Pearce et al., 2022; Fu et al., 2023), which is particularly critical in security-sensitive domains such as financial technologies. Trust in automation therefore becomes a central issue. Lee and See (2004) emphasize that inappropriate reliance may lead to overtrust, a risk also observed in AI coding tools (Vaithilingam et al., 2022).

Beyond productivity and trust, AI-assisted tools influence learning processes. While they can accelerate onboarding and exposure to new technologies (Chen et al., 2021), excessive reliance may reduce deep understanding and critical thinking (Vaithilingam

et al., 2022). This creates a dual effect, highlighting the need for balanced human–AI interaction.

In the context of FinTech, the adoption of AI tools is further shaped by regulatory and ethical considerations. Emerging frameworks such as the EU AI Act emphasize transparency, accountability, and risk management (Veale & Zuiderveen Borgesius, 2021). Given the high sensitivity of financial systems, ensuring trustworthy and secure AI integration is essential.

Despite growing research on productivity and security, there is a lack of survey-based empirical studies examining multidimensional user perceptions—including productivity, performance, learning, and trust—within FinTech contexts. This study addresses this gap by providing an integrated empirical analysis of Copilot usage, contributing to both technology acceptance literature and AI governance discussions.

3 Method

This study employed quantitative research design using a survey method to examine the determinants of Microsoft Copilot usage among software development professionals. Data were collected between November 2025 and February 2026 through online questionnaires distributed via digital platforms. The survey was administered using Google Forms and shared with professionals actively involved in software development, particularly those familiar with AI-assisted coding tools.

A total of 154 responses were obtained and deemed suitable for statistical analysis. Participation was voluntary, and respondents were informed about the purpose of the study. The data collected were analyzed using IBM SPSS Statistics software.

3.1 Research Design and Hypotheses

Based on literature and theoretical background, this study proposes that perceived benefits and trust-related factors influence Copilot usage behavior.

The research model assumes that Copilot Usage is the dependent variable, while general usage habit, productivity, performance, learning and development, trust, and sectoral impact are independent variables.

In the measurement tool, 5-point Likert statements are scored as "I strongly disagree (1)", "I disagree (2)", "I am undecided (3)", "I agree (4)", "I strongly agree (5)". The scale does not contain any reverse-scored statements. In our study, the Cronbach Alpha internal consistency coefficient was calculated as 0.962.

Accordingly, the following hypotheses were formulated:

H1: Gender does not have a statistically significant effect on Copilot-supported benefit usage dimensions in the FinTech sector.

H2: The frequency of Copilot usage has a statistically significant and positive effect on Copilot-supported benefit usage across multiple dimensions in the FinTech sector.

H3: The area of Copilot usage (profession) has a statistically significant effect on selected dimensions (general usage, sectoral impact, productivity, and performance) of benefit usage in the FinTech sector.

H4: Education level has a statistically significant effect on selected dimensions (general usage and performance) of Copilot-supported benefit usage in the FinTech sector.

H5: Experience has a limited and dimension-specific effect on Copilot-supported benefit usage, primarily influencing the general usage dimension in the FinTech sector.

4 Results and Discussion

Data were analyzed using SPSS 31.0.2.0 with a 95% confidence interval and a significance level of $p < 0.05$. Normality was assessed using Shapiro-Wilk and Kolmogorov-Smirnov tests, and non-parametric methods were applied.

The Mann–Whitney U test results indicate that there are no statistically significant differences between male and female participants across any of the sub-dimensions ($p > 0.05$ for all variables). This suggests that gender does not play a determining role in the usage, perception, or evaluation of AI-assisted development tools.

Although female participants exhibit slightly higher mean ranks in most dimensions—particularly in general usage, sectoral impact, and performance—these differences are not statistically significant. Therefore, they should be interpreted as marginal tendencies rather than meaningful disparities.

The findings imply that AI-assisted coding tools provide a relatively gender-neutral experience, where both male and female users benefit similarly in terms of productivity, learning, and performance. This is an important result in the context of technology adoption, as it suggests that such tools do not reinforce gender-based differences in software development environments.

Overall, the results support the conclusion that gender is not a significant factor influencing either the adoption or perceived effectiveness of AI-supported development tools, highlighting their inclusive and broadly accessible nature.

Table 1: Evaluation of Technology Acceptance and Its Subdimensions According to Gender

Sub-dimension	Gender	N	Mean Rank	U	Z	P*
General Usage	Male	96	74.57	2503.000	-1.054	0.292
	Female	58	82.34			
Sectoral Impact	Male	96	74.12	2459.500	-1.218	0.223
	Female	58	83.09			
Productivity & Efficiency	Male	96	77.25	2760.000	-0.091	0.928
	Female	58	77.91			
Performance	Male	96	73.64	2413.000	-1.399	0.162
	Female	58	83.90			
Learning & Development	Male	96	75.40	2582.500	-0.764	0.445
	Female	58	80.97			
Trust & Critical Perspective	Male	96	76.01	2641.000	-0.538	0.590
	Female	58	79.97			

*Mann–Whitney U Test. * $p < .05$ indicates statistical significance.

The findings presented in Table 2 reveal that usage frequency has a statistically significant effect on multiple dimensions of Copilot-supported benefit utilization. The Mann–Whitney U test results indicate significant differences between participants who use the system every day and those who have never used it in the dimensions of general usage ($U = 98.000$, $p = .022$), productivity and efficiency ($U = 101.500$, $p = .025$), performance ($U = 109.500$, $p = .037$), learning and development ($U = 103.500$, $p = .027$), and trust and critical approach ($U = 101.500$, $p = .026$).

In all these dimensions, participants who reported daily usage demonstrated substantially higher mean rank scores compared to those who reported never using the system, indicating more positive evaluations regarding system effectiveness, usability, and contribution to professional tasks. This consistent pattern suggests that frequent interaction with Copilot enhances users' perceptions of its overall value and functional benefits.

Table 2: Evaluation of Technology Acceptance and Its Subdimensions According to General Usage

Sub-dimension	Frequency Of Use	N	Mean Rank	U	Z	P*
General Usage	Every Day	74	42.18	98.000	-2.295	0.022
	Never Used	6	19.83			
Sectoral Impact	Every Day	74	41.92	117.000	-1.935	0.053
	Never Used	6	23.00			
Productivity & Efficiency	Every Day	74	42.13	101.500	-2.243	0.025
	Never Used	6	20.42			
Performance	Every Day	74	42.02	109.500	-2.088	0.037
	Never Used	6	21.75			
Learning & Development	Every Day	74	42.10	103.500	-2.213	0.027
	Never Used	6	20.75			
Trust & Critical Perspective	Every Day	74	42.13	101.500	-2.231	0.026
	Never Used	6	20.42			

*Mann–Whitney U Test. *p <.05 indicates statistical significance.

Overall, these findings demonstrate that usage frequency is a critical determinant of perceived benefit and system evaluation. Regular use appears to strengthen user experience, improve perceived productivity and performance outcomes, and enhance learning and trust-related perceptions. These results support the argument that continuous exposure and active engagement with AI-assisted tools play a key

role in maximizing their perceived effectiveness and adoption in the FinTech context.

The results presented in Table 3 indicate that profession plays a statistically significant role in shaping several dimensions of technology adoption. Specifically, statistically significant differences were observed in general usage ($p < .001$), sectoral impact ($p = .038$), productivity and efficiency ($p = .005$), and performance ($p = .045$) between software developers/engineers and participants from other professional backgrounds.

Across these dimensions, software developers consistently demonstrated higher mean rank scores compared to other professionals. This finding suggests that individuals with a technical background tend to perceive AI-assisted tools such as Copilot as more beneficial, effective, and performance-enhancing. Their familiarity with software development processes, coding environments, and digital tools likely contributes to stronger perceived usefulness and more efficient system utilization.

In contrast, no statistically significant differences were found in the learning and development ($p = .119$) and trust and critical perspective ($p = .066$) dimensions. Although developers again showed higher mean ranks, these differences did not reach statistical significance. This suggests that perceptions related to learning outcomes and trust in AI systems may be influenced by broader cognitive or organizational factors rather than profession alone.

Overall, the findings indicate that professional background, particularly being a software developer, constitutes an important determinant of perceived system utility, productivity gains, and performance outcomes. However, its influence appears to be more limited in shaping trust-related perceptions and learning experiences. These results highlight the importance of domain-specific familiarity and technical competence in maximizing the perceived benefits of AI-assisted development tools.

The findings presented in Table 4 indicate that educational level has a statistically significant effect on several dimensions of technology adoption. Specifically, general usage, sectoral impact, productivity and efficiency, and performance show statistically significant differences across education groups ($p < .001$ for all dimensions). These results suggest that education level is an important determinant of how individuals perceive and utilize AI-assisted technologies

Table 3: Evaluation of Technology Acceptance and Its Subdimensions According to Occupational Group

Sub-dimension	Profession	N	Mean Rank	U	Z	P*
General Usage	Developer / Engineer	74	44.62	190.000	-3.491	< .001
	Other	6	21.07			
Sectoral Impact	Developer / Engineer	74	42.96	299.500	-2.071	.038
	Other	6	28.89			
Productivity & Efficiency	Developer / Engineer	74	43.80	244.500	-2.792	.005
	Other	6	24.96			
Performance	Developer / Engineer	74	42.86	306.000	-2.007	.045
	Other	6	29.36			
Learning & Development	Developer / Engineer	74	42.34	340.500	-1.558	.119
	Other	6	31.82			
Trust & Critical Perspective	Developer / Engineer	74	42.67	318.500	-1.839	.066
	Other	6	30.25			

*Kruskal–Wallis H Test. *p < .05 indicates statistical significance.

A clear pattern emerges in which university graduates consistently demonstrate the highest mean rank scores, followed by master’s degree holders, while high school and PhD participants report comparatively lower scores in most dimensions. This trend indicates that individuals with a university-level education tend to perceive greater benefits, higher efficiency, and stronger performance outcomes when using AI-based tools such as Copilot.

Interestingly, the results do not reveal statistically significant differences in the learning and development ($p = .052$) and trust and critical perspective ($p = .096$) dimensions, although both are close to the significance threshold. This suggests that while education level strongly influences practical and performance-related perceptions, its impact on learning outcomes and trust-related evaluations is more limited.

Furthermore, the Jonckheere–Terpstra test results ($p < .05$) indicate a significant ordered trend across education levels for most dimensions, reinforcing the presence of a systematic relationship between education and technology perception. However, the relatively lower scores observed among PhD participants may reflect

differences in expectations, critical evaluation tendencies, or lower reliance on such tools for routine tasks.

Overall, these findings suggest that educational level plays a crucial role in shaping perceptions of usefulness, efficiency, and performance, while its effect on trust and learning remains comparatively weaker. This highlights the importance of considering both cognitive and contextual factors when evaluating technology adoption across different educational backgrounds.

Table 4: Evaluation of Technology Acceptance and Its Subdimensions According to Educational Level

Sub-dimension	Education	N	Mean Rank	χ^2	P*
General Usage	University	91	91.47	24.755	< .001
	Master's Degree	52	61.50		
	High School	7	38.79		
	PhD	4	35.38		
Sectoral Impact	University	91	89.79	19.470	< .001
	Master's Degree	52	62.79		
	High School	7	55.43		
	PhD	4	27.88		
Productivity & Efficiency	University	91	88.08	16.756	< .001
	Master's Degree	52	67.05		
	High School	7	45.14		
	PhD	4	29.25		
Performance	University	91	89.77	21.250	< .001
	Master's Degree	52	64.88		
	High School	7	37.64		
	PhD	4	32.13		
Learning & Development	University	91	84.72	7.747	.052
	Master's Degree	52	68.79		
	High School	7	70.21		
	PhD	4	39.25		
Trust & Critical Perspective	University	91	84.78	6.339	.096
	Master's Degree	52	67.40		
	High School	7	59.71		
	PhD	4	74.25		

*p < 0.005 indicates statistical significance. Kruskal–Wallis Test

Table 5 presents the results of H5. The Kruskal–Wallis test results indicate that professional experience has a statistically significant effect only on the “General Usage” dimension ($\chi^2 = 10.163$, $p = 0.038$). Specifically, individuals with 2–5 years of experience exhibit the highest mean rank, suggesting that mid-level professionals

tend to use AI-assisted tools more actively compared to both less experienced and highly experienced individuals.

Table 5: Evaluation of Technology Adoption and Its Sub-Dimensions by Groups Based on Professional Experience

Sub-dimension	Experience	N	Mean Rank	χ^2	P*
General Usage	0–1 years	7	63.43	10.163	0.038
	2–5 years	49	88.68		
	6–10 years	39	78.97		
	11–15 years	41	76.63		
	16+ years	18	51.31		
Sectoral Impact	0–1 years	7	71.21	2.634	0.621
	2–5 years	49	81.74		
	6–10 years	39	75.96		
	11–15 years	41	81.01		
	16+ years	18	63.72		
Productivity & Efficiency	0–1 years	7	59.57	6.019	0.198
	2–5 years	49	88.98		
	6–10 years	39	76.92		
	11–15 years	41	71.06		
	16+ years	18	69.14		
Performance	0–1 years	7	64.29	7.336	0.119
	2–5 years	49	86.66		
	6–10 years	39	82.76		
	11–15 years	41	72.30		
	16+ years	18	58.14		
Learning & Development	0–1 years	7	61.36	3.849	0.427
	2–5 years	49	81.60		
	6–10 years	39	81.99		
	11–15 years	41	77.61		
	16+ years	18	62.64		
Trust & Critical Perspective	0–1 years	7	74.93	1.734	0.784
	2–5 years	49	79.67		
	6–10 years	39	75.22		
	11–15 years	41	82.16		
	16+ years	18	66.92		

*p < 0. 005 indicates statistical significance. Kruskal–Wallis Test.

For all other dimensions, including sectoral impact, productivity, performance, learning, and trust–no statistically significant differences were observed ($p > 0.05$). This suggests that perceptions regarding the broader impacts of AI-assisted development tools are relatively consistent across different experience levels.

Interestingly, the results reveal a non-linear pattern: while early-career professionals (0–1 years) and highly experienced individuals (16+ years) demonstrate lower mean ranks, mid-career professionals (2–10 years) show higher engagement and perceived benefits. This may indicate that mid-level developers are more adaptable to new technologies and more actively integrate AI tools into their workflows.

Overall, the findings suggest that experience level influences actual usage behavior more than perception, highlighting the importance of targeting different experience groups with tailored adoption strategies in organizations.

5 Conclusion

This study aimed to investigate the impact of demographic and behavioral factors on Copilot-supported benefit usage in the FinTech sector. Based on the empirical findings, revised hypotheses were developed to better align with the observed statistical evidence.

The results indicate that **gender does not have a statistically significant effect** on any of the examined dimensions. This finding supports H1 and suggests that perceptions of Copilot-supported benefits are consistent across genders, indicating a gender-neutral adoption and evaluation pattern.

In contrast, **frequency of Copilot usage emerges as the most influential factor**. Statistically significant and positive differences were observed across multiple dimensions, including general usage, productivity, performance, learning and development, and trust and critical approach. These findings strongly support H2 and highlight that frequent interaction with AI tools enhances perceived benefits and effectiveness.

The analysis of **profession (area of usage)** reveals statistically significant differences in general usage, sectoral impact, productivity, and performance, while no significant differences were found in learning and development or trust-related dimensions. Therefore, H3 is supported, demonstrating that professional roles shape how users perceive the practical and operational benefits of Copilot.

Regarding **education level**, statistically significant differences were identified in general usage and performance dimensions, whereas other dimensions did not show significant variation. Thus, H4 is supported, indicating that education influences certain functional aspects of Copilot usage but does not uniformly affect all dimensions.

Finally, **experience has a limited and selective impact**. A statistically significant effect was observed only in the general usage dimension, with no meaningful differences across other dimensions. These findings support H5 and suggest that experience alone is not a comprehensive predictor of Copilot-related benefit perception.

Overall, the study demonstrates that **behavioral engagement (usage frequency)** is a more critical determinant of perceived benefits than **demographic characteristics (gender, education, experience)**. This underscores the importance of promoting active and sustained use of AI-supported tools in the FinTech sector to maximize their value and impact.

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ENVIRONMENTAL ACCOUNTING AND ESG INTEGRATION IN HUNGARY'S ENERGY SECTOR: A STUDY OF THE TOP CORPORATIONS AND THEIR SUBSIDIARIES

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This study investigates environmental accounting, corporate sustainability, and ESG practices of the top energy sector companies (Mol Magyar Olaj- és Gázipari Plc., MVM Energetika Plc., E.ON Hungária Energetikai Ltd., Veolia Energia Magyarország Plc., and their subsidiaries) in Hungary, selected based on the HVG Top 500 company ranking. The research focuses on how leading energy firms incorporate environmental considerations into their accounting systems and sustainability strategies in response to increasing regulatory, stakeholder, and market pressures. Emphasis is placed on the role of ESG reports and Notes to the financial statements as a key instrument of environmental accounting, as these disclosures provide critical qualitative and quantitative information on environmental liabilities, provisions, emissions-related risks, sustainability investments, and compliance with environmental regulations. Using a qualitative content analysis of annual reports, sustainability reports, and ESG disclosures, the study evaluates the transparency, consistency, and depth of environmental information disclosed by the sampled companies. Findings reveal notable differences in the scope and quality of environmental and ESG reporting, especially regarding the use of Notes to enhance accountability and stakeholder understanding. The research contributes to the literature by highlighting the importance of financial statement disclosures in strengthening ESG credibility and supporting sustainable decision-making within the Hungarian energy sector.

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1 Introduction

Over the last 10 years, environmental accounting and the consideration of ESG factors have become increasingly important in companies' reporting practices, especially in the energy sector. As a result of the tightening of the regulatory environment in the European Union, especially the EU Taxonomy Regulation, the non-financial reporting requirements, and the new sustainability reporting standards, the transparent and quantitative reporting of environmental performance has become not only a reputational issue for companies but also a financial one.

The purpose of this research is to investigate how the main players in the Hungarian energy market, namely Mol Magyar Olaj- és Gázipari Plc., MVM Energetika Plc., E.ON Hungária Energetikai Ltd., Veolia Energia Magyarország Plc., reflect the main components of environmental accounting in their financial reports and ESG disclosures, and to what extent they offer comparable, consistent, and quantitative information on climate risks, environmental liabilities, and sustainability-related investments.

The study is grounded in a qualitative document analysis, which, employing a structured coding approach, investigates the level of disclosure of environmental liabilities and provisions, the share of sustainability goals and expenditures, the degree of detail of emissions information, and the degree of integration between financial and ESG disclosures. The analysis focuses on the level of disclosure of environmental accounting components in the notes to the financial statements and their degree of integration with strategic reports. The research contributes to the comparative evaluation of ESG practices in the Hungarian energy sector and reveals differences in reporting practices, best practices, and opportunities for improving the integration of environmental accounting and sustainability reporting.

2 Literature review

The conceptual and theoretical basis of sustainability has become an integral part of scientific and economic discourse in the second half of the 20th century (Veres, 2025). The global character of environmental issues was recognized from the very beginning, underscoring that they do not confine themselves to national borders but demand a systemic approach (Kerekes et al., 1995). Whereas sustainable

development has historically been viewed from within the paradigm of the Triple Bottom Line concept (Brundtland Commission, 1987), recent legislative changes have transformed the language of sustainable development into a mandatory financial disclosure language.

There are two types of sustainability models: weak and strong. Weak sustainability relies on the substitutability of capital, which holds that natural capital can be replaced to a limited extent by human or physical capital (Pepper, 1998; Kerekes, 2008). Strong sustainability, on the other hand, prioritizes biophysical constraints and argues that some essential components of natural capital cannot be replaced (Meadows et al., 1972). Daly (1991) argues that any economic growth and ecological sustainability can be considered sustainable only if the growth rate does not exceed the limits of environmental sustainability. The question of sustainability is not one that can be studied in a vacuum; it involves the complex interaction of a multitude of factors and relationships.

2.1 Corporate sustainability

The corporate understanding of sustainability involves applying the principles of sustainable development to economic actors (Dyllick & Hockerts, 2002). The idea of corporate sustainability rests on the understanding that corporations are not just profit-seeking organizations but are socially embedded systems whose activities have profound impacts on the environment and society (Elkington, 1997). The social acceptability of corporate activities is increasingly contingent on the organization's ability to balance economic, social, and environmental factors in its strategy (Porter & Kramer, 2011).

The idea of a company is treated differently in economic and legal theories. According to Coase's (1937) transaction cost theory, the significance of a company is to minimize the cost of market coordination. Firms mitigate informational asymmetries and agency problems by using ESG information in the financial notes, thus providing a universal language for risks to investors that narrative sustainability reporting does not have. Chikán (2008) describes a company as a business enterprise with legal personality that functions as part of a larger social system. Stakeholder theory is a crucial aspect of understanding the relationship between the company and its environment, in which the company's responsibility is not only to its

shareholders but to all stakeholders (Freeman, 1984). Donaldson and Preston (1995) describe the stakeholder theory in three dimensions: descriptive, instrumental, and normative, stressing that the company has a moral duty to its stakeholders. Under Stakeholder Theory, the Notes to the financial statements reflect the highest degree of responsibility because they convert environmental costs into auditable financial obligations affecting the interests of stakeholders.

The corporate sustainability approach is grounded in the Triple Bottom Line, which considers social and environmental performance alongside financial performance (Elkington, 1997). Corporate sustainability is a long-term strategic approach that complements economic rationality with social and environmental responsibility, according to Beckmann and Pies (2004). Steuer et al. (2005) argue that the needs of the company and its stakeholders can only be met by conserving natural and human resources. Montiel and Delgado-Ceballos (2014) indicate that corporate sustainability is a more deeply integrated strategic paradigm than CSR, and its role is to preserve corporate value in the long term. According to Pazienza et al. (2022), corporate sustainability ensures intergenerational equity between the environmental, social, and economic pillars.

On the other hand, Blinova et al. (2022) provide an interpretation specific to the industry. In this case, business sustainability includes durability, value conservation, and the potential for sustainable development. They also highlight the importance of efficient ESG (Environmental, Social, Governance) management and the use of the circular economy approach in business strategy. This helps businesses better position themselves in line with sustainable development objectives. According to the OECD (2024), business sustainability involves integrating environmental and social aspects into business strategy, which supports risk management and transparent business governance.

2.2 Accounting reflection of sustainability approach

Sustainability is one of the biggest social and economic challenges that we face today. At an organizational level, sustainability requires organizations to factor in the social and environmental implications of their operations, in addition to meeting their economic objectives. Organizational sustainability is thus not only a matter of corporate social responsibility but also a strategic way to ensure that the

organization's value and acceptability, as well as its environmental impact, are maintained in the long term. This is closely related to environmental accounting, which uses accounting techniques to ensure an organization's environmental performance is measurable and traceable. The objective of environmental accounting is to provide information on the use of environmental assets, pollution, environmental investments and costs, and their long-term economic effects, beyond traditional financial measures.

The accounting reflection of the sustainability approach emerged through the development of environmental accounting. Accounting, as the language of business (Riahi-Belkaoui, 2005), traditionally concentrated on the measurement and reporting of economic events. Nevertheless, the conventional accounting system has not been proven to be appropriate for the comprehensive recording of environmental effects (Ván, 2012). Environmental accounting has thus emerged as a subsystem of the accounting system capable of incorporating environmental costs, risks, and performance measures (Csutora & Kerekes, 2004).

The evolution of environmental accounting can be broken down into several stages (Ván, 2012). It began in the 1960s and 1970s in the context of social accounting, as a reaction to the growing environmental issues (Gray & Bebbington, 2001). The publication of the Club of Rome's report "The Limits to Growth" marked a paradigm shift in understanding the link between economic growth and environmental constraints (Meadows et al., 1972). In the 1980s, the growing practice of corporate environmental reporting and the rise in industrial accidents brought environmental accountability back into focus (Adams, 2004). Since the 1990s, environmental accounting has developed its own conceptual and methodological foundations (Schaltegger & Burritt, 2000).

In the conceptual development phase, the definition of obligations has shifted from reporting obligations (Senge, 1993) to integrated management of financial and physical data (UNSD, 2001). According to Bennett et al. (2003), the aim of environmental accounting is to provide financial and non-financial information on sustainable economic and environmental performance. In Hungarian literature, Csutora (2001) and Pál (2003) highlight the importance of environmental cost disclosure and decision support. Environmental accounting has thus developed into a tool for measuring and communicating corporate sustainability. In Ván's (2012)

interpretation, we can read that the environmental accounting system reflects on environmental challenges, considers and deals with environmental problems at the corporate level, and, last but not least, assists in quantifying environmental performance.

For a long time, the traditional accounting system was primarily economic in nature, and thus, environmental factors were only marginally taken into account. Pete & Nagy (2007) point out that this was due to several reasons. On the one hand, the neoclassical economic paradigm treated natural resources as free goods for a long time, so their social costs were not accounted for in the accounting system. Secondly, there was no appropriate methodology for valuing the physical environment. Thirdly, the accounting system's short-term focus was unable to cope with environmental effects and savings on a longer-term basis. Nagy (2013) further lists information aggregation as a problem. Thus, while it is easy to generate standardized, aggregated information, environmental information that is difficult to quantify in monetary terms may be lost in the aggregation process.

2.3 The transition between environmental accounting and ESG

The shift from environmental accounting to ESG represents a new era in the institutionalization of sustainability information. ESG (Environmental, Social, Governance) is a framework that combines environmental, social, and governance factors into a single evaluation process. The ESG approach is more than a question of business ethics; it is also a means of facilitating investment decisions by measuring non-financial risks and opportunities (Veres et al., 2025).

The improvement of the ESG regulatory framework at the European level became a determining factor with the adoption of the European Sustainability Reporting Standards (ESRS) by the European Commission on July 31, 2023. The ESRS aims to create a harmonized, comparable sustainability reporting framework within the European Union that incorporates environmental, social, and governance factors into corporate reporting. The ESRS requires mandatory measurement of corporate sustainability through standardized indicators and disclosure obligations (Krivogorsky, 2024). The ESRS is also aligned with the EU legal framework, meaning its reporting obligations are consistent with other EU regulations and

frameworks, such as the Sustainable Finance Disclosure Regulation (SFDR) and the EU Taxonomy (Goerzen et al., 2025).

The ESRS is categorized into two broad groups: mandatory and comprehensive standards, and thematic standards. Under the "mandatory, comprehensive standards, ESRS 1 and ESRS 2," ESRS 1 outlines the fundamental compliance and requirements for CSRD compliance and ensures compatibility with the fundamental standards for sustainable reporting. ESRS 1 is accompanied by ESRS 2, which outlines the general disclosure obligations. This standard addresses three major areas: governance, strategy, and impact, risk, and opportunity management (Hummel & Jobst, 2024).

ESG, the EU Green Deal, and the EU Taxonomy are three important aspects of the European Union's sustainability regulatory framework. Each aspect of the regulatory framework plays a distinct role, but all three determine which sustainable business activities are permitted in the European Union (Vela Almeida et al., 2023). The EU Taxonomy is a classification system for sustainable economic activities. The EU Taxonomy identifies which economic activities are environmentally sustainable. The purpose of the EU Taxonomy is to promote green investments and prevent greenwashing by providing an objective measure of environmental performance (European Parliament & Council, 2020).

One of the basic purposes of the Taxonomy Regulation is to create a common regulatory framework for sustainable investments, thereby helping market participants, especially financial institutions, identify activities that are positive from an environmental and sustainability perspective. The lack of a common definition in the past posed the risk that some companies or economic activities might be incorrectly identified as "green," leading to greater greenwashing. The regulation helps avoid this issue by ensuring that economic activities identified as sustainable are assessed using common criteria across the European Economic Area (Brabec & Macháč, 2025).

Taxonomy and ESRS form the basis of a new era of sustainability reporting, in which environmental accounting principles are incorporated into the financial reporting system. The development of ESG, ESRS, and the EU Taxonomy is the institutional outcome of several decades of environmental accounting. Sustainability reporting is

no longer a voluntary corporate communication instrument, but a regulated, audited, and comparable data set. This development elevates corporate sustainability to a strategic management and financial decision-making process, reinforcing the relationship between sustainability and accounting.

3 Data and methodology

The current research employs a qualitative design, focusing on document analysis, to investigate how environmental accounting and ESG factors are incorporated into the reporting practices of the most prominent Hungarian energy corporations. The research takes an exploratory, descriptive approach to determine patterns, differences, and levels of transparency in environmental disclosures. The qualitative content analysis technique was found to be most suited to the research question since the objective is to reveal the level and quality of the interpretation of the disclosures beyond any statistical metrics. As there has been a change from a voluntary to a mandatory requirement for the disclosure of these risks and liabilities, such an approach is deemed fitting.

In light of increasing regulatory pressure, stakeholder expectations, and market-driven sustainability demands, qualitative content analysis was identified as the most suitable methodology for analyzing the extent, form, and consistency of environmental information conveyed through corporate disclosures. This study specifically concentrates on the use of Notes to the financial statements and ESG reports as tools of environmental accounting.

The empirical sample comprises the best-performing companies in Hungary's energy sector, selected from the HVG Top 500 ranking. Based on the company ranking, the following corporations and their consolidated subsidiaries were included in the analysis:

- Mol Magyar Olaj- és Gázipari Plc.,
- MVM Energetika Plc.,
- E.ON Hungária Energetikai Ltd.,
- Veolia Energia Magyarország Plc.

The empirical sample consists of four system-level energy companies that have been chosen from the HVG Top 500 list. The firms have not been chosen only due to profitability considerations; rather, they have been chosen based on their importance in terms of being the key earners and system operators in the energy sector of Hungary. Such a sample will ensure that the research is able to look at companies facing the toughest regulatory scrutiny (ESG Act, EU Taxonomy) as well as having the highest environmental footprint.

The study relies solely on publicly available company filings, including the following: annual financial statements (consolidated and individual statements where applicable), notes to the financial statements, sustainability reports, ESG reports, and associated disclosures. These sources were chosen because they are the primary official channels companies use to disclose information on their environmental performance, environmental liabilities, sustainability investments, regulatory compliance, and ESG risks.

Special attention is drawn to the Notes to the financial statements, which provide systematic qualitative and quantitative disclosures on environmental provisions, contingent liabilities, risks associated with emissions, environmental investments, and compliance costs. These disclosures are viewed as an important interface between conventional financial accounting and environmental accounting. The research applies qualitative content analysis as the main analytical technique. The analysis was conducted in several stages:

– Coding Process Description

The procedure used in coding involved an inductive-deductive methodology, as follows. *Deductive Category Development*: a framework for coding was developed using the European Sustainability Reporting Standards (ESRS) and the literature on environmental accounting, specifically in relation to seven themes: liabilities/provisions, investments (CAPEX), emission risks, regulations, strategy, governance, and report integration. *Analysis Methods*: reports were examined in terms of clarity (availability of particular information), consistency (comparability between the Notes and ESG reports), and specificity (audited quantitative financial information as opposed to just narratives). *Cross-Case Analysis*: results were then compared in order to reveal any discrepancies between cases. onThe treatment of

environmental accounting components in the Notes to the financial statements was particularly important for analytical purposes.

– Cross-Company Comparison

Based on analyses of individual companies, a comparative analysis was conducted to identify similarities and differences in reporting practices. This helped to find trends, reporting gaps, and best practices in environmental and ESG reporting in the Hungarian energy sector.

What characterizes this study is the emphasis on the Notes to the financial statements as tools of environmental accounting. Although sustainability and ESG reports include narrative and strategic sustainability information, the Notes include legally bound, audited, and financially quantified information. In general, the data collection and qualitative approach used in this study enable a systematic assessment of the integration of environmental accounting and ESG transparency in the Hungarian energy sector, with a focus on the financial statement Notes as a link between traditional accounting and sustainability reporting.

4 Results of the companies examined

The sustainability transformation of the energy industry has emerged as one of the most important structural shifts in corporate governance, strategic planning, and accounting systems over the last ten years. The decarbonization challenges, the European Union's climate policy goals, the ESRS reporting requirements, and investor demands have cumulatively forced large corporations to integrate sustainability into their operations. In Hungary, there are four major energy and utility companies that function as system-level actors, and their sustainability performance not only impacts their own business but also the entire corporate system in the country. These companies are Mol Magyar Olaj- és Gázipari Plc., MVM Energetika Plc., E.ON Hungária Energetikai Ltd., Veolia Energia Magyarország Plc. (Muck, 2025).

Act C of 2000 on Accounting states that entities of public interest are obliged to make a non-financial statement. In this regard, the companies that are obliged to publish a sustainability report are those enterprises for which, on the balance sheet

date of the previous business year, at least two of the following three indicators have exceeded the thresholds for any two consecutive business years:

- balance sheet total: 10,000 million HUF,
- net sales revenue: 20,000 million HUF, and the
- average number of employees: 250 people (Act C on Accounting).

The purpose of the ESG Act of 2023 is to improve supply chain transparency and standardize the provision of ESG information to make comparisons easier (Act CVIII of 2023). Regarding the implementation of the law, the MOL report provides a comprehensive explanation of supplier chain audits (human rights, environmental compliance), one of the law's main points. E.ON ensures compliance with its supplier requirements in its “Partner Code.” The format of the reports (tables in accordance with GRI guidelines) serves as a basis for providing information in compliance with the law. Based on the above points, it can be concluded that the sustainability reports of all four companies comply with the legal regulations.

The companies under review meet the statutory requirements. MVM and MOL prepare integrated reports that present financial and sustainability information in a single document, meeting the highest transparency standards. Another characteristic of the reports is that they are audited by independent auditors, usually at the “limited assurance” level.

According to the 2024 reporting data (Table 1), all the companies examined meet the law's requirements, which require each of them to publish a sustainability report as part of their report. MOL and MVM published their group-level sustainability reports alongside their financial reports. E.ON, however, published its sustainability report online, offering a shorter and a much more detailed version. Veolia Plc. met the criteria but failed to publish a sustainability report in Hungarian either in the e-report or on their own website. The company follows the environmental activities of its international corporate group as its main strategic approach, including social responsibility, transformation, and environmentally focused innovation activities. Hence, the study relies on the English-language group-wide ESG report.

Table 1: Criteria for Compliance in Sustainability Reporting

Criteria	Mol Magyar Olaj- és Gázipari Plc.	MVM Energetikai Plc.	E.On Hungária Energetikai Ltd.	Veolia Energia Magyarország Plc.
Balance sheet total 10,000 million HUF	5,314,811 million HUF	3,881,424 million HUF	719,947 million HUF	169,074 million HUF
Net sales revenue: 20,000 million HUF	3,349,746 million HUF	56,080 million HUF	18,240 million HUF	76,440 million HUF
Average number of employees: 250	4,731 people	19,314 people	436 people	538 people
Sustainability report	uploaded as part of the Financial Statement	uploaded as part of the consolidated Financial Statement	available on the E.On Hungária Group website	ESG report available in English only

Source: the Authors' own editing

Among the chosen companies, under a strategic agreement, MVM Energetika Plc. took over ÉMÁSZ Hálózati Ltd. on August 31, 2021, and E.ON Áramszolgáltató Ltd. on April 14, 2022. E.ON Beteiligungen GmbH holds a 75% stake in the E.ON Hungária group through E.ON Hungária Plc, and the remaining 25% is owned by MVM Plc, the central holding company of the MVM Group. The following analysis, in a detailed and publication-ready scientific format, will discuss the environmental accounting, ESG performance, strategic goals, and future challenges of the four companies.

4.1 Mol Magyar Olaj- és Gázipari Plc.

MOL Plc. is an integrated oil, gas, petrochemical, and consumer services business that has recently expanded its activities to include waste management as a new strategic business area. The company is a leading player in Central and Eastern Europe. Its sustainability report may be viewed as a document that reflects a deep transformation in the industry. The company has traditionally been an integrated oil and gas business, covering the entire value chain from exploration and production in the upstream segment to refining and petrochemicals in the downstream segment, and including retail as well. At the heart of its ESG transformation is the “Shape Tomorrow” strategy (MolGroup, 2025).

4.1.1 Environmental Accounting and ESG Disclosure

The analysis of MOL Plc.'s environmental accounting and ESG reporting practices was conducted through a structured qualitative coding analysis of the consolidated annual report, the integrated report, and the sustainability report. The analysis covered environmental liabilities, emissions, sustainability-related investments, and the integration with financial statements.

The company's total greenhouse gas emissions are several million tons of CO₂ equivalent per year, and the largest share, about 70-80%, is classified under Scope 1. Scope 2 emissions account for less than 10%, while Scope 3 emissions, especially those associated with product use, are significant and can account for more than half of the total emissions.

MOL has also targeted reducing Scope 1 and 2 emissions by at least 30% by 2030, compared to the baseline year, and achieving net-zero emissions across the value chain by 2050. According to the company's reports, a substantial portion of the total annual investment is allocated to sustainability and low-carbon initiatives. This includes investment in the development of the circular economy, waste recovery, biofuel production, and green hydrogen initiatives.

Based on disclosures under the EU Taxonomy, a portion of the company's revenue and investments, typically ranging from 20% to 30%, is considered taxonomy-compliant. The notes to the financial statements include a detailed breakdown of environmental provisions, particularly those related to mining and upstream activities, including reclamation and decommissioning costs. These are shown at their discounted present value and form a substantial part of the long-term liabilities, which reflect the company's long-term environmental stewardship in its activities.

4.1.2 Climate Risks, Regulatory Context, and Strategic Integration

In the case of MOL, the main risk of climate change is transition risk. The increase in carbon prices and the subsequent tightening of the EU Emissions Trading System have a direct effect on refining margins and the cost structure of energy-intensive production. According to the company, carbon prices can influence the operating profit by tens of millions of euros every year.

The “Shape Tomorrow” strategy targets that low- and zero-carbon business activities should contribute at least 30% to EBITDA by 2030. Through the development of the circular economy business and the waste management concession, the company processes several million tons of waste every year, which, in the long term, could reduce the weight of the fossil-based business.

The physical risks of climate change, for example, natural weather-related disasters, primarily concern infrastructure operations, but the financial aspect is less detailed.

The ESG management structure is set up within the framework of board-level oversight, and part of the management compensation is tied to ESG performance.

Compliance with regulations is addressed systematically in the reports, including the use of the EU Taxonomy, GRI, and TCFD recommendations. Having the sustainability report audited by an external party enhances the credibility of the data, while financial sensitivity analysis for climate scenarios is a development area.

4.1.3 Evaluation According to Analytical Criteria

Based on document coding, MOL reporting is highly transparent, especially regarding emissions data and the percentage share of sustainability-related investments. The 30% target for emissions reduction, the 40% share of sustainable investments, and the 20-30% share of taxonomy-aligned activities allow for industry comparisons.

Consistency is essentially guaranteed through the reporting structure, but the direct financial quantification of climate risks is not always provided in numerical terms. The level of detail is considerable, especially regarding strategic goals and emissions information, which improves comparability with other energy corporations. On the other hand, differences in methodology regarding Scope 3 emissions could prevent a full comparison.

In summary, MOL's environmental accounting and ESG activities can be seen as a meaningfully integrated system, supported by quantitative indicators, where the growing proportion of sustainability investments and the decarbonization targets indicate a gradual shift in the business model. The way forward would be to further

develop the financial modeling of climate risks and to integrate ESG indicators even more closely with the financial statements, thereby providing a stronger basis for comparison.

4.2 MVM Energetika Plc.

MVM Energetika Plc. is the third-largest corporate group in Hungary by revenue and encompasses the entire value chain, from production to trading and customer service. It accounts for around 60% of the country's total electricity production, of which 83% is carbon-neutral, mainly due to the Paks Nuclear Power Plant. Among its subsidiaries, such as MVM CEEnergy Plc., MVM Next Energiakereskedelmi Plc., MAVIR Plc., MVM Partner Energiakereskedelmi Plc., and many others, most are ranked on the HVP TOP 500 list. Its sustainability strategy focuses on the two-fold goal of energy security and decarbonization. It supplies around 60% of the country's total electricity production, of which 83% is carbon-neutral, mainly due to nuclear energy. The carbon intensity in 2024 was 56 gCO₂e/kWh, which is very low even globally (MVM Csoport, 2025).

4.2.1 Environmental Accounting and ESG Disclosure Structure

The study of the environmental accounting and ESG reporting practices of MVM Energetika Zrt. was conducted through structured qualitative coding of the consolidated annual report, the sustainability report, and the notes to the financial statements. One of the most important aspects of the company's electricity generation mix is that more than 60% of its electricity is generated through nuclear power, resulting in low direct carbon dioxide emissions. This makes the carbon intensity more favorable than that of the fossil-fuel-based energy mix in Europe.

Based on the sustainability reports, it can be seen that over 90% of the company's total greenhouse gas emissions are Scope 1 emissions, mainly attributable to its production pattern. Scope 2 emissions are relatively low, whereas disclosure of Scope 3 emissions is still in development.

Among the company's strategic goals is the target to decrease direct (Scope 1) emissions by at least 40% from the baseline year by 2030, as well as to further increase the share of low-carbon sources in electricity production. According to the

reports, the share of renewable energy sources in the overall production structure is steadily increasing, exceeding 10%, while the share of fossil-based sources is declining.

In the financial reports, environmental liabilities, particularly decommissioning and reclamation liabilities for power plant assets, are disclosed at their discounted present value. These provisions form a substantial part of the company's long-term liabilities, reflecting the capital-intensive and long-term nature of its business activities. Investments in environmental protection and sustainability account for more than one-third of the total annual investment outlay. On the basis of the EU Taxonomy compliance data, a substantial amount of the investments made by the company, ranging from 30% to 40% in some years, has been classified as sustainable economic activity, which indicates a transition towards decarbonization.

4.2.2 Climate Risks, Regulatory Context, and Strategic Integration

The climate risks to which MVM is exposed can be understood in two dimensions. On the one hand, physical risks such as extreme weather events and heatwaves can affect operational reliability, while on the other hand, transition risks are driven by rising carbon prices, the reduction of the emissions trading system, and the scrapping of fossil fuel capacity.

The company's strategic target is to achieve carbon neutrality in Scope 1 and Scope 2 in the medium term. The change at the Mátra Power Plant is a particularly important structural change, as the reduction in lignite production may result in a decline of more than 50% at the affected facilities. From an accounting perspective, there are also questions about asset impairment and future investment obligations.

Regarding regulatory compliance, the company has fully integrated the requirements of the EU Emissions Trading System, with the result that carbon costs are indirectly reported in the income statement. The assurance of the sustainability reports provided by external parties increases the credibility of the reported information, but the financial sensitivity analysis of climate change scenarios is not yet fully quantified. The ESG governance system is at the executive level, and sustainability indicators are becoming increasingly important in evaluating executive performance.

4.2.3 Evaluation According to Analytical Criteria

Based on document coding, the reporting of MVM shows a high level of transparency, especially in the form of the energy mix and the percentage share of emissions. The portfolio share of low-carbon sources above 60%, together with the target to reduce emissions by 40% and the allocation of over a third of investments to sustainable activities, allows comparisons to be made.

Consistency is ensured between the financial and sustainability reports, as environmental provisions and decommissioning requirements are disclosed in an organized manner in the notes to the financial statements. Nevertheless, the disclosure of the financial effects of climate risks, such as the impact of carbon price changes on the bottom line, could be further improved. The level of detail regarding energy strategy goals and emissions information is important, though disclosure of Scope 3 emissions remains a point for improvement. The 30-40% share of sustainable investments under the EU Taxonomy improves international comparability, though the classification of nuclear energy remains a matter of interpretation.

In summary, MVM's environmental accounting and ESG activities demonstrate a systematic, strategically integrated approach with quantitative indicators, in which decarbonization and energy security serve as a joint foundation for the company's long-term value-creation model. The future development could focus on more detailed financial analysis of climate risks and on extending emissions data to the entire value chain, enabling even more precise sector-level conclusions in the cross-company comparison section.

4.3 E.On Hungária Energetikai Ltd.

The company has several electricity distribution subsidiaries that are 100% owned. Among these, the following companies are ranked in the HVG Top 500: E.ON Észak-dunántúli Áramhálózati Plc. (119), E.ON Dél-dunántúli Áramhálózati Plc. (218), ELMŰ Hálózati Ltd. (73), and E.ON Energiamegoldások Ltd. (48) (Muck, 2025). The companies engage in electricity distribution and other non-licensed activities under permits issued by the Hungarian Energy and Public Utility Regulatory Authority.

The distribution business includes electricity transmission and distribution, as well as the planning, implementation, operation, maintenance, and development of high-voltage lines, transformers, and switchgear. The major non-licensed activity is the leasing service for the companies' passive infrastructure assets. The subsidiaries deliver electricity distribution services in ten counties (Győr-Moson-Sopron, Vas, Zala, Fejér, Komárom-Esztergom, Veszprém, Baranya, Somogy, Tolna, and Pest) and the city of Budapest, covering a total area of about 43,500 km².

4.3.1 Environmental Accounting and ESG Disclosure Structure

The analysis of E.ON Hungária Plc.'s environmental accounting practices was conducted using structured qualitative coding of the company's consolidated financial statements, sustainability reports, and notes to the financial statements. The objective of the analysis was to determine the extent to which environmental liabilities, emissions, and sustainability-related investments are integrated into the financial reporting system, and whether they provide comparable and consistent information.

The analysis of E.ON Hungária Plc.'s environmental accounting practices was conducted using structured qualitative coding of the company's consolidated financial statements, sustainability reports, and notes to the financial statements. The objective of the analysis was to determine the extent to which environmental liabilities, emissions, and sustainability-related investments are integrated into the financial reporting system, and whether they provide comparable and consistent information.

The company has also set a target to reduce operational emissions by at least 50% by 2030 compared to the baseline year and plans to achieve carbon-neutral operations in the Scope 1 and Scope 2 categories in the medium term. Expenditure on network development and digitalization accounts for more than 60% of annual capital expenditure, a substantial share of which – 40-50% in some years – is dedicated to sustainability or climate change adaptation initiatives.

On the basis of disclosures made as part of the EU Taxonomy, more than half of the investments of the company, exceeding 50%, fall under sustainable economic activities, especially in the development of distribution network infrastructure.

Environmental liabilities are shown in the notes to the financial statements, but their amount is lower than that of production-oriented companies. Long-term liabilities mainly comprise reclamation and decommissioning obligations for network assets, which are disclosed at their discounted present value.

4.3.2 Climate Risks, Regulatory Context, and Strategic Integration

The climate risks that threaten E.ON's business activities can be understood from both physical and regulatory perspectives. The physical risks, including the effects of natural weather events, directly affect the distribution network's functioning, potentially impacting supply security and leading to higher maintenance costs. The transition risks are primarily driven by changes in the regulatory framework, carbon pricing, and more stringent energy efficiency standards.

The company's strategic objective is to increase the integration of renewable energy sources into the grid and reduce distribution losses by at least 10% by 2030. Expenditures on digitalization and the installation of smart metering systems help improve efficiency and reduce emissions. The effect of carbon costs on the company's performance is less direct compared to production-oriented companies; nevertheless, changes in the regulatory framework influence return rates and capital structure.

The ESG governance framework functions in an integrated way, with monitoring at both the executive and group levels. The use of sustainability indicators in executive performance reviews indicates the level of strategic integration. External assurance of the reports enhances the credibility of the data and enables international comparisons.

4.3.3 Evaluation According to Analytical Criteria

Based on document coding, it can be seen that E.ON Hungária's reporting is highly transparent, especially in the composition of network investments and the structure of emissions. The 50% reduction in emissions and the share of taxonomy-aligned investments above 50% indicate the importance of sustainability. The sustainability-oriented investments of 40-60% of total CAPEX indicate the structural transformation.

Consistency between the financial and ESG reports is fundamentally ensured, especially regarding investment information and network development projects. The level of detail is important for strategic and investment purposes, but disclosure of Scope 3 emissions can be further improved to enhance comparability (E.ON, 2025).

In general, the environmental accounting and ESG activities of E.ON Hungária demonstrate a well-structured system that uses quantitative indicators, with the development of the network and digitalization at the focal point of the decarbonization strategy. The future development could focus on preparing a more detailed financial sensitivity analysis of climate risks, which would enable even more precise comparisons in the cross-company section.

4.4 Veolia Energia Magyarország Plc.

Veolia is one of the main actors in the energy, water, and waste sectors in Hungary, with more than 30 years of experience serving municipalities, institutions, and companies to ensure efficient resource management. Moreover, it provides clean drinking water and heating for thousands of households in Hungary. Veolia Energia Magyarország Plc., as part of the international Veolia group, pursues an integrated approach to ecological transformation (Veolia, 2025).

4.4.1 Environmental Accounting and ESG Disclosure Structure

The case study on the environmental accounting and ESG reporting practices of Veolia Energia Magyarország Plc. was conducted by analyzing the financial statements, notes to the accounts, and group-level sustainability reports. The business model of Veolia Energia Magyarország Plc. is based on energy production, industrial energy services, and district heating.

A large part of the operational emissions is categorized under Scope 1, mainly because of natural gas-based heating and electricity generation. The Scope 2 emissions are moderate, whereas Scope 3 emissions, especially those associated with the supply chain and the extraction of used fuels, are large, although they are only partly disclosed on an aggregated basis. Based on group-level information, Veolia's worldwide operations emit tens of millions of tons of CO₂ equivalent every year,

although more than a 10% reduction in operational emissions has been achieved through decarbonization initiatives.

The company's target is to cut operational emissions by around 50% relative to the 2018 baseline by 2030, and to achieve net-zero emissions by 2050. The investment plan of the Hungarian subsidiary is also in line with this target. A substantial part of the total annual CAPEX, around 40% in some years, is allocated to energy efficiency, biomass, or waste heat recovery projects. The main investments are in modernizing combined heat and power (CHP) plants, which can lead to primary energy savings of 15-20%.

Based on the EU Taxonomy disclosures, over 60% of the group investments fall under sustainable activities in the waste management and water utilities business segments. In the Hungarian energy business, the proportion of taxonomy-aligned investments is lower but indicates an upward trend. The financial statement notes include provisions for decommissioning and reclamation, which are presented at their discounted present value.

4.4.2 Climate Risks, Regulatory Context, and Strategic Integration

In Veolia's business, the risks associated with climate change primarily relate to transition risks. The rise in carbon prices, the evolution of the EU Emissions Trading System, and the increase in energy efficiency standards directly affect costs. Carbon costs are a material financial risk for gas-based production, but the rise in the use of biomass and waste-based technologies can help to mitigate this risk.

Physical risks of climate change, such as heatwaves and other weather-related events, may also affect the functioning of energy infrastructure and water services. The company's risk management framework takes a comprehensive approach to these issues, and, as reported, climate change risks and opportunities are considered in the strategic planning process.

The group's ESG governance framework is established at the board level, and a portion of executive compensation is tied to sustainability performance indicators. The reports are externally assured, which helps in the credibility of the data. The use of climate scenarios, especially the 1.5°C scenario, is incorporated in the strategic

documents, although the level of financial sensitivity analysis could have been further enhanced.

4.4.3 Evaluation According to Analytical Criteria

Based on document coding, the level of transparency in Veolia Energia Magyarország's reporting is found to be adequate regarding the disclosure of emission reduction targets and investment shares. The 50% reduction in emissions, the 40% share of sustainability-themed investments, and the more than 60% share of group-level taxonomy-aligned investments highlight the transition.

The consistency between the financial report and the sustainability report is essentially guaranteed, especially regarding decommissioning costs and environmental expenditures. The level of detail is important for the presentation of strategic plans and energy efficiency schemes; nevertheless, a further detailed segmentation of Scope 3 emissions would be beneficial for comparison with other energy firms.

In summary, Veolia's environmental accounting and ESG activities are part of a well-integrated system with quantitative indicators, where enhancing energy efficiency and increasing the share of alternative fuels are important elements in pursuing decarbonization goals. Future improvement might lie in further refining the financial effects of climate risks, which would enable a more refined industry-level evaluation in the cross-company comparison section.

5 Conclusion and discussion

A comparison of the environmental accounting and ESG activities of the four companies clearly reveals that there has been both structural and substantive progress in sustainability reporting in the Hungarian energy sector. However, the intensity of integration and the level of detail in financial mapping differ considerably across companies.

Table 2: Comparative Environmental and Taxonomy Metrics

Criteria	Mol Magyar Olaj- és Gázipari Plc.	MVM Energetikai Plc.	E.On Hungária Energetikai Ltd.	Veolia Energia Magyarország Plc.
Emissions Reduction Target (by 2030)	30%	40%	50%	50%
EU Taxonomy Alignment (Investments)	20–30%	30–40%	Over 50%	60% (Group level)
Sustainability-Themed CAPEX Share	40%	Over 33%	40–60%	40%
Carbon Neutrality Goal	2050	Medium-term (S1&S2)	Medium-term (S1&S2)	2050
Primary Emission Category	Scope 1 (70–80%)	Scope 1 (Over 90%)	Distribution losses/infrastructure	Scope 1 (Gas-based)

Source: the Authors' own editing

5.1 The Institutionalization of Environmental Accounting and Divergent Business Models

The findings show that a company's business model is the key determinant of its emphasis on environmental accounting. In the case of MOL, which is production-based and fossil fuel-related, the emphasis is on minimizing Scope 1 and Scope 2 emissions, improving carbon intensity, and decommissioning and reclamation provisions. On the other hand, MVM's diversified generation mix, which includes substantial nuclear and renewable power, has a different emissions profile, shifting the emphasis of its sustainability plan.

For E.ON, with a network and service profile, the environmental accounting is mainly focused on investments in network development, loss reduction, and financing of taxonomy-aligned infrastructure. For Veolia, the focus is on integrating energy and circular-economy businesses, where energy-efficiency schemes and the use of alternative fuels are directly linked to reducing emissions.

This difference in structure underscores the point that environmental accounting cannot be standardized but must be tailored to each company's value chain and risk profile. On the other hand, the need for comparability requires the use of standardized methodological approaches, especially for categories and taxonomies of emissions.

5.2 Transparency, Consistency, and Financial Integration

Based on the analysis of the document, it can be said that transparency is improving. This is because the use of percentages (for example, 30-50% reduction of emissions by 2030), the percentage of sustainability investments (40-60% of CAPEX), and the use of taxonomy-aligned activities are improving comparability.

However, the integration of financial statements and ESG reports has not yet been achieved. Although the environmental provisions, decommissioning obligations, and carbon costs are included in the notes to the financial statements, the financial sensitivity analysis of climate risks is still qualitative. A more detailed presentation of future carbon price scenarios, climate components in discounted cash flow models, and climate assumptions in impairment tests would further improve the quality of the reports.

5.3 Highlighting Divergence in Scope 3 Reporting

One of the important findings of this analysis is the inconsistency in the methodology employed regarding Scope 3 emissions, thereby making it impossible to conduct a comprehensive benchmarking in terms of quantitative measurement of the environmental impact of the organizations:

- MOL Plc has reported substantial Scope 3 emissions, including customer side emissions resulting from combustion of the products, accounting for more than 50% of its overall emissions.
- MVM Plc reports that Scope 3 reporting is still under development and therefore current reporting concentrates on Scope 1 emissions (emissions that relate to production).

- E.ON Hungária concentrates on reporting relating to network efficiency and energy losses during distribution; Scope 3 emissions are not specified in detail.
- Veolia Energia reports that Scope 3 emissions (mainly in connection with fuel extraction and supply chain emissions) are substantial; however, these are currently reported on a consolidated group level, not on the company level.

The difference brings to light an important “reporting gap” in the industry. Although there is already increasing standardization of Scope 1 and 2 emissions owing to regulatory pressure (such as the EU ETS), Scope 3 emissions have not yet been standardized. In the context of regulatory agencies and investors, the lack of such standardization poses a challenge in determining the actual carbon footprint involved in the energy transition process. Regarding consistency, integrated reporting models offer it; however, differences in methodology for Scope 3 emissions prevent a full comparison. Standardization of the different calculation bases and data collection methods would be essential for benchmarking.

5.4 Regulatory Environment and Future Challenges

Looking ahead, one of the most important factors is the continued consolidation of the European Union's sustainability regulatory framework, especially regarding the CSRD and ESRS standards. This will lead to higher expectations for data quality, auditability, and digital reporting. This not only poses an administrative problem for companies but also requires the development of data collection and control systems within the company.

The expected increase in carbon pricing, the expansion of the EU Emissions Trading System, and the strengthening of energy efficiency standards could have direct financial effects. Those companies that integrate climate risks into their strategic and financial planning processes in a timely manner could gain a competitive advantage in terms of capital market perception and financial costs.

It is clear from the above study that the key energy firms operating within Hungary have gradually aligned themselves with the regulatory requirements concerning financial and non-financial reporting. The present research demonstrates the increasing tendency among key players of the Hungarian energy market to adapt their financial and non-financial reporting according to the legal requirements and

thus enhancing transparency and accountability of organizations. The contribution of the paper is clearly presented in three categories - theoretical, methodological and practical:

- Theoretical contribution: this research integrates two opposing accounting theories, namely Traditional Accounting Theory and Stakeholder Theory by proving that "Notes to the financial statements" is the essential tool through which companies transform the concept of environmental liability into a legal obligation. Additionally, this paper contributes to the discussion in the field of Strong vs. Weak Sustainability since it evaluates if energy companies perceive natural capital as the internalizable expense or simply a reputational one.
- Methodological contribution: the present research offers an analytical approach towards assessing financial and non-financial integration by focusing on "Notes to the financial statements" instead of sustainability brochures.
- Practical Contribution to Policy Makers: the results illustrates the absence of standards in reporting Scope 3 emissions and the qualitative assessment of the climate risk sensitivity analysis, indicating where there is room for future policy enforcement in the light of the CSRD framework.
- Practical Contribution to Corporate Management: The research reveals best practices in the Hungarian energy industry, like those of MVM and MOL, providing guidance for smaller companies operating in the new ESG regulated area.

Future challenges will be the quantitative proof of the relationship between sustainability performance and financial performance. The growing use of green finance instruments, such as sustainability bonds and ESG-linked loans, demands credible, audited, and quantitative reporting. Environmental accounting will therefore not only be a reporting instrument but also a strategic component of corporate value creation.

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SPATIAL AND SOCIO-DEMOGRAPHIC PATTERNS OF URBAN LIGHT POLLUTION AND FUTURE INTERVENTIONS

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Urban light pollution is an increasingly important environmental and public-health issue, yet its socio-demographic distribution within cities remains insufficiently explored. This paper presents an exploratory spatial comparison of nighttime illumination patterns and selected socio-demographic indicators in Győr, Hungary. The analysis draws on publicly available territorial statistics and mapped light-pollution data to examine whether areas with higher illumination intensity overlap with population groups that may be more vulnerable to nighttime environmental disturbance, particularly elderly and lower-income residents. Rather than testing causal relationships, the paper identifies indicative spatial patterns and evaluates the analytical potential of combining environmental and demographic datasets in urban research. The results suggest that the most intensely illuminated parts of the city are associated with the historical core, major transport corridors, and older high-density residential areas, which also show higher aging indices and less favourable income profiles. These findings point to a potential environmental inequality embedded in the city's socio-spatial structure. From a policy perspective, the paper argues that lighting strategies should incorporate socio-demographic considerations alongside efficiency and safety objectives in order to support more equitable and sustainable urban governance.

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1 Introduction

Cities play a central role in sustainability transitions, as they concentrate population, infrastructure, and resource consumption while also offering substantial potential for efficiency gains and environmental governance (Macher & Szigeti, 2025; Sipos et al., 2023). Consequently, integrating environmental considerations into urban planning and management has become a key objective of sustainable development strategies at local, national, and global scales (Macher & Beke, 2025; Magyar & Macher, 2023). Artificial light at night (ALAN) has become an integral component of contemporary urbanization, accompanying economic development, transport systems, and expanding service economies (Jiang et al., 2022). While urban illumination improves safety, mobility, and nighttime economic activity, its uncontrolled growth has also produced a distinct environmental externality in the form of urban light pollution (Bresson et al., 2023; Gaston & Sánchez de Miguel, 2022; Zielinska-Dabkowska et al., 2023).

Despite growing awareness of its ecological and health-related effects, the socio-spatial distribution of light pollution within cities remains comparatively underexplored (Gaston & Sánchez de Miguel, 2022; Zielinska-Dabkowska et al., 2023). In particular, fewer studies examine whether population groups with different socio-demographic characteristics are exposed to similar or unequal nighttime environmental conditions. This issue is especially relevant in urban areas where land use, transport infrastructure, service concentration, and housing-market dynamics shape both illumination patterns and residential structures.

This paper addresses that gap through an exploratory case study of Győr, Hungary. Rather than measuring causal effects, it asks whether publicly available territorial and illumination datasets reveal spatial overlaps between nighttime light intensity and selected indicators of potential social vulnerability, namely aging structure, population concentration, and income differences. Accordingly, the paper pursues three objectives:

- 1) to describe the intra-urban spatial pattern of nighttime illumination in Győr;
- 2) to compare this pattern with selected socio-demographic indicators; and
- 3) to discuss how such exploratory spatial evidence may inform more targeted urban lighting governance and future empirical research.

The remainder of the paper is structured as follows. Section 2 reviews the theoretical background on ALAN, environmental justice, and urban governance. Section 3 presents the methodology and data sources. Section 4 reports the empirical results, while Section 5 discusses their implications and limitations. Section 6 concludes.

2 Theoretical background

2.1 Artificial light at night as an urban sustainability challenge

Urban lighting reflects broader socio-economic processes, including mobility patterns, land-use intensity, and commercial concentration (Chang et al., 2025). From an environmental perspective, ALAN disrupts ecological cycles by altering species behaviour, migration patterns, and biodiversity composition. Landscape-scale analyses demonstrate that night lighting fragments habitats in ways comparable to transport infrastructure, creating barriers for nocturnal organisms (Challéat et al., 2021; Johnston et al., 2025; Sanders et al., 2020). Similarly, large-scale environmental assessments emphasize that nighttime illumination represents a cross-cutting pressure affecting terrestrial, freshwater, and urban ecosystems simultaneously (Gaston & Sánchez de Miguel, 2022). These findings position light pollution not merely as an aesthetic issue but as a structural ecological stressor (Hao et al., 2024).

In parallel, research increasingly identifies significant human health implications. Artificial nighttime exposure interferes with circadian rhythms by suppressing melatonin production, contributing to sleep disorders, metabolic disruption, and potentially elevated chronic disease risks (Moore-Ede et al., 2023). Epidemiological reviews link long-term nighttime illumination exposure to cardiovascular and psychological outcomes, especially among vulnerable populations (Jiménez et al., 2025; Zielinska-Dabkowska et al., 2023). Because sleep quality and biological rhythms are strongly tied to environmental conditions, urban lighting becomes a public-health concern rather than a purely infrastructural one (Bará & Falchi, 2023; Linares Arroyo et al., 2024).

2.2 Light pollution and environmental justice

Urban environmental hazards often follow patterns of environmental inequality, where disadvantaged communities experience disproportionate exposure to noise, air pollution, or heat stress (Nadybal et al., 2020). Recent studies suggest similar

patterns for nighttime illumination: dense housing areas and lower-income neighbourhoods frequently experience higher luminance levels due to traffic corridors, commercial zoning, and infrastructural placement (Xiao et al., 2023). Such findings indicate that lighting infrastructure can unintentionally reproduce social inequalities within the urban environment (Tong et al., 2024). The environmental justice perspective therefore provides an important conceptual framework (Wilson et al., 2025).

Unequal exposure does not necessarily arise from intentional planning decisions but rather from the interaction of land-use zoning, market forces, and technological deployment (Eakin et al., 2022). Commercial districts tend to concentrate high-intensity lighting, while lower-income residential zones often border major transport routes or industrial areas (Silm et al., 2024). Consequently, socially vulnerable groups may experience disproportionate nighttime exposure. Urban environmental justice research increasingly calls for integrating demographic indicators into environmental assessments to identify these hidden inequalities (Helbich et al., 2024).

2.3 Governance and technological transition

Technological transitions further complicate the issue. The rapid adoption of LED lighting, often promoted as an energy-efficient sustainability solution, has paradoxically contributed to increased brightness due to rebound effects and higher blue-spectrum emissions (Schulte-Römer et al., 2019). While LEDs reduce energy consumption, their spectral composition enhances skyglow and biological impact unless carefully managed (Gaston et al., 2012). This demonstrates that sustainability interventions must consider environmental, social, and technological dimensions simultaneously.

In response, urban planning literature emphasizes smart lighting as a governance tool rather than a purely technical upgrade (Fazia et al., 2025; Munonye et al., 2025). Adaptive lighting systems can maintain safety while minimizing exposure. However, implementation requires coordination between municipalities, infrastructure operators, and communities, highlighting the importance of cross-sectoral governance (Jørgensen & Ma, 2025; Lewandowski et al., 2022). Without socio-spatial prioritization, technological solutions risk reinforcing existing inequalities rather than alleviating them (Giest, 2025; Moghayedi, 2025; Varzeshi et al., 2025).

The literature suggests that urban light pollution should be interpreted at the intersection of environmental sustainability, public health, and social equity. However, empirical studies still more often focus either on physical measurement or ecological impact, while fewer combine demographic variables with spatial urban analysis. This paper contributes to that gap through an exploratory, city-level comparison of socio-demographic and illumination patterns in Győr.

3 Methodology

This paper applies an exploratory and interpretative spatial research approach to assess whether existing publicly available datasets can support the identification of socio-spatial patterns of urban light pollution. The paper does not aim to estimate causal relationships, produce new remote-sensing measurements, or test statistical associations. Instead, it evaluates whether already available environmental and demographic data reveal plausible spatial overlaps that may justify more detailed future analysis. The empirical focus of the paper is the city of Győr, Hungary. The analysis is based on publicly available territorial statistics provided by the Hungarian National Spatial Development and Planning Information System (TEIR) (National Regional Development and Spatial Planning Information System, 2026). The database integrates census and administrative data and provides settlement-level and intra-urban indicators relevant for environmental and social assessment.

From this system, variables were selected that are theoretically linked to sensitivity to artificial light at night, including the aging index, permanent population distribution, and income-related indicators where available. These variables represent demographic vulnerability rather than environmental exposure itself, allowing the identification of groups that may experience different levels of impact under similar environmental conditions.

Environmental exposure is represented through an existing mapped source of nighttime illumination intensity. In this paper, the light-pollution map is used as a secondary visualized environmental dataset rather than as a newly processed remote-sensing product. Accordingly, the paper interprets relative spatial differences in illumination intensity in relation to the socio-demographic indicators. The analysis does not distinguish between public lighting, commercial lighting, transport-related

lighting, or household-level emissions; instead, it examines the aggregated spatial pattern of nighttime illumination visible at the city scale.

The analysis therefore compares two independent but spatially interpretable data domains: socio-demographic indicators derived from TEIR and mapped nighttime illumination patterns derived from the selected light-pollution source. The aim is to assess whether their spatial distributions plausibly overlap in ways that may indicate uneven exposure conditions across the city. The analytical framework follows a qualitative comparison logic. Rather than testing statistical correlations, the paper examines whether areas characterized by higher illumination appear to correspond to locations with socially sensitive populations, such as a higher share of elderly residents, lower income levels, or higher residential concentration. These relationships are treated as indicative spatial patterns rather than measured effects, and they are interpreted as hypothesis-generating observations.

Accordingly, the results are not presented as causal evidence but as an assessment of the analytical potential of territorial data integration. The methodology demonstrates how environmental and demographic datasets can inform urban environmental governance even in the absence of advanced modelling. The approach highlights the role of publicly accessible spatial information in supporting early-stage planning discussions, identifying priority areas, and framing future research directions.

The paper also has clear limitations. First, it is a single-city exploratory case study and therefore does not support generalization to Hungary as a whole. Second, the analysis is descriptive and interpretative; it does not quantify exposure, health outcomes, or statistical significance. Third, the light-pollution source captures aggregated nighttime illumination patterns and does not allow the separate identification of specific light sources. The purpose of this preliminary step is therefore to support subsequent research phases involving spatial statistics, exposure modelling, and targeted intervention evaluation.

4 Results

4.1 Urban morphology and social zoning

The spatial datasets indicate that the city follows a layered urban structure typical of medium-sized Central European cities. A compact inner core of dense, closed urban fabric is surrounded by large housing estate areas, which transition into lower-density suburban neighbourhoods dominated by detached housing. Although this pattern initially appears purely morphological, the demographic indicators reveal that it simultaneously functions as a social zoning mechanism. The central districts concentrate permanent residents and everyday urban activity, while the outer zones function primarily as residential environments with a stronger daily commuting rhythm. This functional differentiation implies that environmental exposure in the city is shaped less by simple distance from the centre and more by the intensity of urban use. The city therefore operates not only as a density gradient but also as an activity gradient, which is particularly relevant when assessing nighttime environmental pressures (Figure 1.).

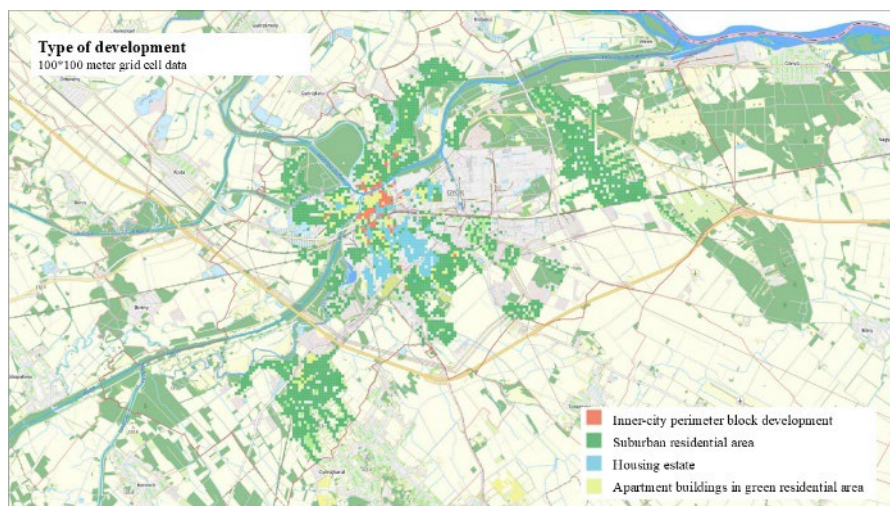


Figure 1: Type of development

Source: National Regional Development and Spatial Planning Information System, 2026

4.2 **Aging index: concentration of sensitive populations**

Among the examined variables, the aging index presents the clearest spatial structure. Higher proportions of elderly residents appear consistently in the inner city and in earlier-developed high-density residential areas. Peripheral family-house districts show considerably lower values, indicating a younger demographic profile. This distribution reflects long-term residential stability. Older residents tend to remain in accessible, service-rich neighbourhoods where healthcare, shops, and public transport are available within short distances. Younger households, particularly families with children, are more strongly represented in newly developed suburban environments. The spatial consequence is that population groups that may be more sensitive to nighttime environmental disturbance are concentrated in the most continuously active parts of the city (Figure 2).

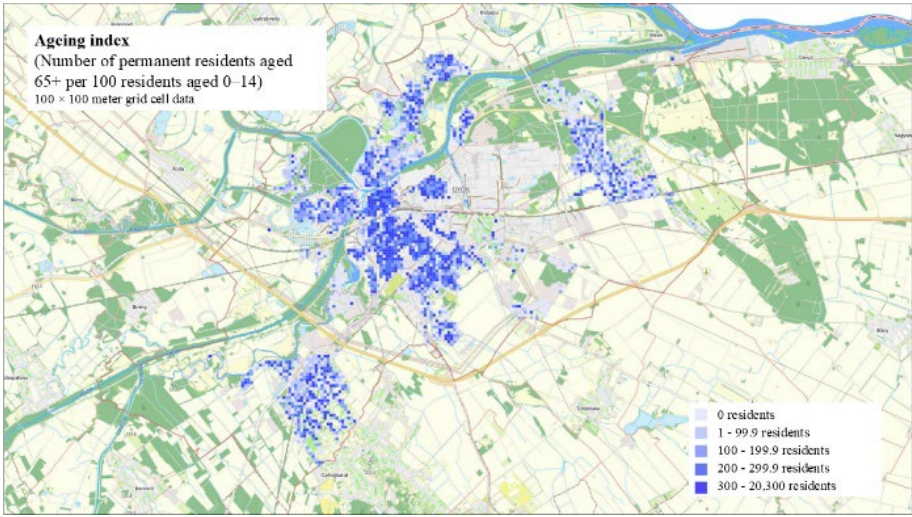


Figure 2: Ageing index

Source: National Regional Development and Spatial Planning Information System, 2026

4.3 **Population density and activity intensity**

The map of total permanent population shows a strong central concentration combined with secondary clusters along major transport axes (Figure 3).

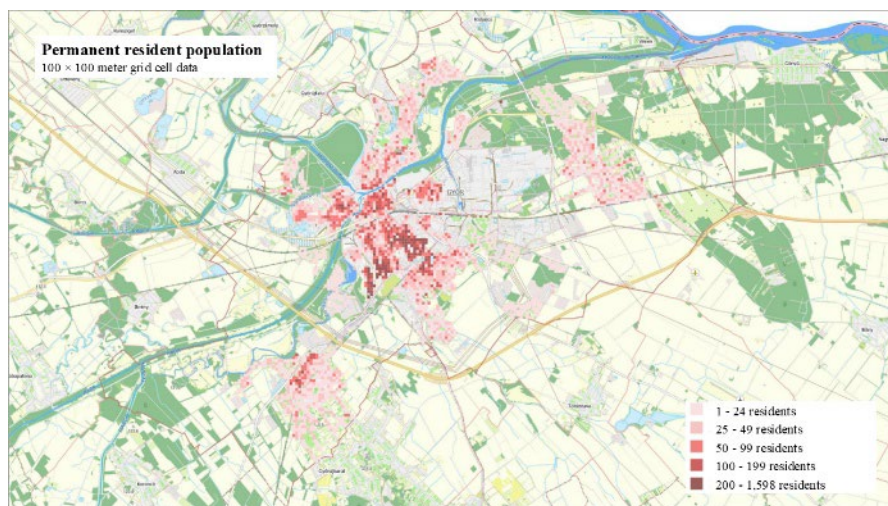


Figure 3: Population density

Source: National Regional Development and Spatial Planning Information System, 2026

Rather than forming a simple concentric decline, the pattern follows mobility infrastructure and service centres. This suggests that human presence is closely linked to accessibility and functional urban nodes. Such areas typically sustain activity beyond daytime hours due to commercial, transport and service functions. From an environmental perspective, the importance of this finding lies in distinguishing density from activity: areas with persistent human presence may also sustain nighttime functions associated with continuous urban operation and infrastructure use.

4.4 Age-group differentiation: children and elderly

The separation of younger (0–14 years) and older (63+ years) populations reveals a clear demographic inversion (Figure 4). Children are concentrated in suburban family-house neighbourhoods and newly developed residential areas, locations characterised by lower building height, reduced traffic intensity, and more regular daily cycles. In contrast, the elderly population overlaps strongly with the dense urban core and older housing estates. This spatial separation indicates that age groups experience fundamentally different urban environments. Younger populations inhabit areas designed primarily for residential use, while older residents remain embedded in multifunctional urban zones. The resulting pattern implies that

exposure to continuous urban conditions is may not be evenly distributed across demographic groups.

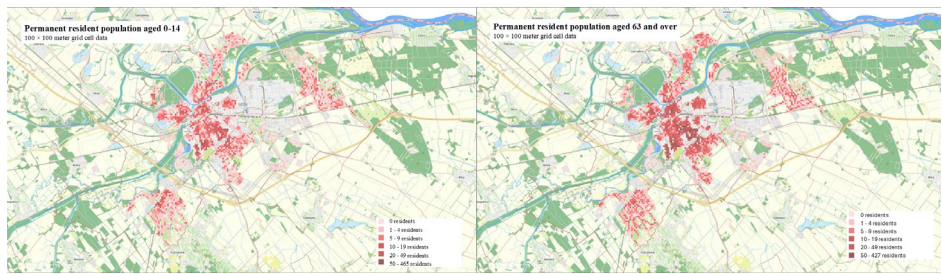


Figure 4: The separation of younger (0–14 years) and older (63+ years) populations
Source: National Regional Development and Spatial Planning Information System, 2026

4.5 **Income structure and socio-economic differentiation**

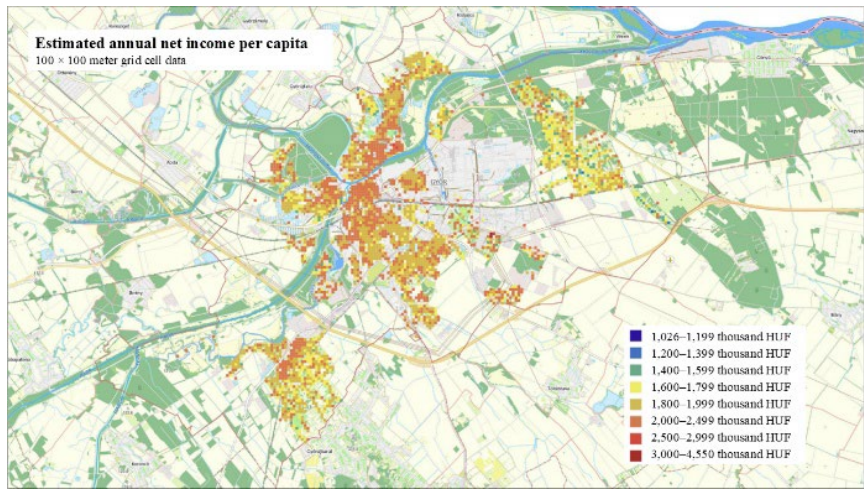


Figure 5: Income structure
Source: National Regional Development and Spatial Planning Information System, 2026

Estimated per-capita income further reinforces the socio-spatial differentiation. Higher income values are predominantly observed in suburban and garden-city areas, whereas central and earlier high-density residential districts show lower income levels. Consequently, accessibility to quieter residential environments appears to correlate with higher socio-economic status. The overlap between lower

income and higher aging index in central zones suggests limited residential mobility for certain groups. Populations with fewer economic resources remain in locations shaped by historical development patterns and infrastructure concentration, while higher-income households relocate toward lower-intensity residential environments.

4.6 Emerging vulnerability pattern

Taken together, the datasets describe a coherent spatial configuration. Central accessibility zones concentrate elderly and lower-income residents, while peripheral residential zones concentrate younger and economically stronger households. The spatial structure therefore aligns demographic sensitivity with urban intensity. Even without statistical testing, the territorial indicators reveal a differentiated vulnerability landscape at the level of descriptive spatial interpretation. The city's social geography suggests that any environmental pressure associated with continuous urban operation is unlikely to be evenly distributed across the population. Instead, it is expected to follow the same structural logic embedded in the urban fabric.

4.7 Light as a field of urban activity

The light pollution map does not display a simple concentric “centre–periphery” pattern. The highest radiance appears in the historical and functional core, yet not as a single concentrated point but as an extended field of activity stretching along the main transport corridors in several directions. Around the central area an intensive illumination zone emerges, connected through the housing estate belt to major commercial and mobility nodes. This suggests that nighttime light exposure primarily follows functional intensity rather than population size. The spatial distribution is shaped by the city's nocturnal infrastructure, roads, services, parking areas and commercial functions. Consequently, the highest exposure does not occur simply where the largest residential populations are located, but rather where the city operates most continuously after dark.

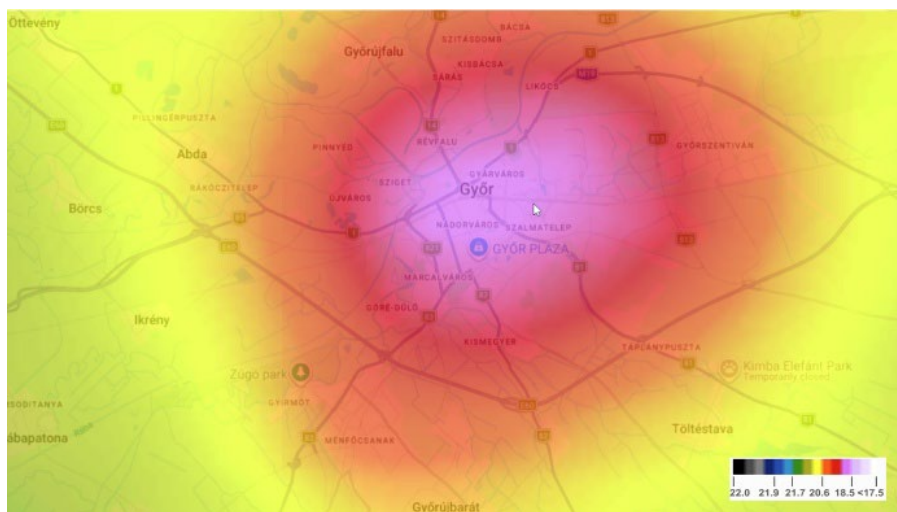


Figure 6: Light pollution in Győr
 Source: <https://www.lightpollutionmap.info>

5 Discussion

When compared with the aging index, one of the clearest spatial relationships becomes visible. Areas with a high proportion of elderly residents largely overlap with the central high-intensity illumination field. The inner city and older housing-estate zones, which display the highest aging-index values, also appear among the brightest parts of the city. This overlap is relevant in light of previous studies suggesting that older populations may be more sensitive to circadian rhythm disturbance and may spend more time within their residential environment. On this basis, the findings do not demonstrate a measured health effect, but they do indicate a potentially relevant exposure configuration that warrants further investigation.

The spatial distribution of the 0–14 age group shows the opposite tendency. Households with children are predominantly concentrated in suburban and peripheral residential areas where illumination intensity appears lower. These neighbourhoods are primarily residential in function, with less nighttime activity and reduced traffic. This produces an inverse pattern: households with children are more frequently located in lower-exposure environments, while elderly populations remain concentrated in higher-intensity urban zones.

The income map adds another interpretative layer. Higher-income households are mainly located in peripheral residential belts, which also correspond to the lowest light exposure zones. The central and older high-density residential areas exhibit lower income levels while simultaneously representing the most illuminated urban environments. This configuration resembles a classic environmental inequality pattern in which higher environmental exposure is associated with fewer adaptive resources. Residential mobility therefore indirectly regulates access to lower-intensity nighttime environments. The maps suggest not only spatial correspondence but also a plausible structural mechanism. The historical development of the city has created a spatial structure in which:

- service-oriented zones remain continuously illuminated,
- these zones host stable, aging populations,
- newer and quieter residential environments are socially selective.

Light exposure therefore appears not as an isolated environmental factor but as a by-product of urban functioning that follows broader socio-spatial patterns. The analysis suggests that nighttime light exposure is unlikely to be evenly distributed across the population. Rather than random variation, the observed patterns point to a form of structurally differentiated exposure embedded in the urban fabric. Illumination intensity follows the logic of functional centrality, and because social groups are unevenly distributed within that structure, environmental burden may also become socially differentiated.

In this configuration, exposure is indirectly regulated by accessibility and housing market dynamics. Central areas, characterised by continuous services, transport infrastructure, and commercial activity, maintain higher levels of nighttime illumination. These same areas host a relatively stable population with higher average age and lower mobility. Peripheral residential zones, by contrast, offer calmer environmental conditions but require greater economic capacity and daily mobility, which selectively favours younger and higher-income households. Consequently, environmental conditions are not only spatially but also socio-economically stratified.

This pattern suggests that light pollution may operate as a form of secondary environmental inequality: it is not intentionally allocated, yet it may systematically affect groups with differing levels of vulnerability and adaptive capacity. The elderly population, which previous literature identifies as potentially more sensitive to circadian disruption, appears concentrated in the most persistently illuminated zones. Meanwhile, populations with greater residential choice and mobility are more frequently located in lower-exposure environments. The resulting configuration links demographic sensitivity, economic capacity, and spatial position.

From an urban governance perspective, this implies that lighting policies should not be evaluated solely through efficiency, safety, or energy considerations. Uniform technical standards may reproduce existing inequalities if they ignore demographic structure. Instead, nighttime lighting can be interpreted as a component of the urban welfare environment, similar to noise or air quality, where distribution matters alongside intensity. The findings therefore support the need for spatially differentiated lighting strategies that integrate demographic information into planning decisions.

At the same time, the present paper has clear limits. Because it relies on descriptive visual comparison within a single city, it cannot demonstrate causality, quantify the magnitude of exposure, or separate the effects of different light sources. These limitations should be addressed in future research through spatial statistics, source-specific lighting analysis, and health-relevant indicators.

6 Conclusions

This paper examined whether publicly available territorial datasets are sufficient to reveal potentially differentiated exposure to urban light pollution before more detailed quantitative modelling is undertaken. By interpreting socio-demographic indicators together with spatial illumination patterns in Győr, the analysis shows that descriptive spatial comparison can already generate relevant hypotheses for urban environmental research and planning. The results suggest that nighttime illumination in the city primarily follows functional urban structure rather than residential density alone. Areas characterized by continuous activity—especially the historical centre, transport corridors, and older high-density residential zones—exhibit the highest light intensity. These same areas also show higher aging indices and less favourable

income profiles, while suburban residential zones with younger and economically stronger households correspond to lower illumination intensity.

Importantly, the observed pattern should not be interpreted as evidence of deliberate allocation, but rather as the outcome of historical urban development, housing-market dynamics, and infrastructure concentration. In this sense, light pollution appears as a secondary outcome of urban functioning that may reproduce broader socio-spatial patterns. From a planning perspective, the results imply that lighting policy should not be treated exclusively as a technical or energy-efficiency issue. Because illumination patterns appear to align with demographic vulnerability, uniform lighting standards may unintentionally reinforce unequal environmental conditions. Integrating demographic indicators into lighting management could therefore improve both environmental quality and social equity without compromising safety or functionality.

The paper makes three contributions. First, it demonstrates the analytical value of combining publicly available territorial data with mapped illumination patterns in an exploratory urban paper. Second, it identifies a plausible spatial overlap between nighttime illumination and socio-demographic vulnerability in Győr. Third, it outlines a planning-relevant framework for identifying priority areas for future intervention and measurement. At the same time, the paper remains limited by its descriptive design, its focus on a single city, and its inability to separate different sources of nighttime illumination or measure health effects directly. Future research should therefore build on this exploratory assessment through spatial statistics, exposure measurement, source-specific lighting analysis, health-related indicators, and the evaluation of targeted urban interventions.

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REGIONAL CIRCULAR ECONOMY KNOWLEDGE HUBS AS FUTURE ENABLERS OF THE GREEN TRANSITION IN EGTC-BASED CROSS-BORDER COOPERATION

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The European Union's transition towards a circular economy necessitates profound technological, institutional, and societal transformations. Regional circular economy knowledge hubs are emerging as potential instruments to facilitate this transition, particularly within EGTC-based cross-border cooperation networks, although their practical implementation remains limited. This paper employs Multi-Level Perspective to explore the prospective role of such hubs, situating them within broader socio-technical landscapes, regional regimes, and niche innovations. Analysis suggests that knowledge hubs could enable the alignment of local competencies, industrial experimentation, and policy frameworks, fostering the development of resilient, regionally embedded circular economy models. By bridging emerging niche practices and established regional structures, these hubs may support the stabilization of sustainable innovations, enhance cross-border learning, and promote inclusive regional development. The research also identifies potential challenges, including institutional fragmentation, uneven resource distribution, and varying levels of stakeholder engagement, which could constrain their future effectiveness. Policy implications highlight the importance of strategically supporting experimental, multi-level initiatives, reinforcing the institutional embedding of knowledge hubs, and encouraging the replication and scaling of successful practices across regions. Although largely conceptual, regional circular economy knowledge hubs could represent a strategic pathway for advancing green transition, enhancing regional resilience, and promoting socially responsible, sustainable development across European territories.

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1 Introduction

The accelerating ecological crisis, increasing resource constraints, and intensifying geopolitical uncertainties have reinforced the urgency of the European Union's green transition agenda (Innella et al., 2024). The transformation towards a circular economy is not merely a technological adjustment but a systemic socio-technical transition requiring coordinated changes across production systems, governance structures, and societal practices (De Felice & Petrillo, 2021; Macher & Szigeti, 2025a). Within this broader transformation, regional scales have emerged as critical arenas for experimentation, institutional innovation, and policy implementation (Crowther et al., 2021). While the circular economy has been extensively discussed in relation to industrial symbiosis, waste valorisation (Macher et al., 2023), and sustainable production models, less attention has been devoted to the institutional architectures that enable regional-level coordination and cross-border alignment (Södergren & Palm, 2021). This gap is particularly relevant in the context of European cross-border regions, where economic interdependencies, asymmetric development levels, and fragmented governance arrangements complicate the operationalisation of circular strategies (Teixeira, 2025; Vanhamäki et al., 2021). European Groupings of Territorial Cooperation (EGTCs) were established to facilitate structured cross-border collaboration, yet their potential role in advancing systemic sustainability transitions remains underexplored (Jańczak, 2016; Øjvind Nielsen et al., 2024).

Existing research on socio-technical transitions, particularly within the Multi-Level Perspective (MLP), has highlighted the importance of niche experimentation, regime destabilisation, and landscape pressures in driving transformation processes (Andersen et al., 2026; F. Geels, 2024; Radtke, 2025). However, the meso-level governance mechanisms that mediate between emerging niche innovations and established regional regimes have received comparatively limited analytical attention, especially in cross-border institutional settings (Bui, 2021; Derudder & Liu, 2025). In this respect, regional circular economy knowledge hubs may represent a missing institutional intermediary capable of facilitating coordination, knowledge circulation, and policy alignment across administrative boundaries (Barrie et al., 2022; Teixeira, 2025). Regional knowledge hubs can be conceptualised as structured platforms that integrate academic expertise, industrial experimentation, policy frameworks, and civil society engagement within territorially embedded networks (Hegyi &

Mariussen, 2021). When embedded in EGTC-based cooperation structures, such hubs may function as cross-border transition intermediaries, enabling the stabilisation and scaling of circular innovations while fostering institutional learning across regions (Cramer, 2020; Dąbrowski et al., 2019). Rather than operating as isolated innovation clusters, they may contribute to the gradual reconfiguration of regional socio-technical regimes by bridging fragmented governance environments and supporting coordinated experimentation (Engels et al., 2019).

Despite their conceptual promise, the practical implementation of regional circular economy knowledge hubs remains limited, and their systemic role within cross-border governance architectures has not yet been thoroughly theorised (Dąbrowski et al., 2019). This paper addresses this gap by exploring how such hubs could function within EGTC-based cooperation frameworks and by situating them within the MLP on sustainability transitions. By integrating transition theory with cross-border governance analysis, the paper aims to advance the understanding of meso-level institutional innovation in the context of the green transition. The central research question guiding this paper is:

RQ: How can regional circular economy knowledge hubs operate as enabling intermediaries of the green transition within EGTC-based cross-border cooperation structures?

To answer this question, the paper develops a conceptual framework that positions knowledge hubs at the intersection of niche experimentation and regional regime transformation. It examines the enabling and constraining institutional conditions shaping their emergence, analyses their potential contribution to resilience and inclusive regional development, and discusses policy implications for scaling and institutional embedding. By focusing on cross-border cooperation structures, this paper contributes to three strands of literature: (1) circular economy governance at the regional scale, (2) socio-technical transition theory, particularly the MLP, and (3) cross-border institutional innovation within the European Union. In doing so, it proposes a refined understanding of regional knowledge hubs as strategic enablers of the green transition and as potential catalysts for territorially embedded, socially responsible, and resilient circular economy pathways.

2 Theoretical Background

The transition towards a circular economy represents a systemic transformation that extends beyond technological substitution or incremental efficiency improvements (Jakubowski & Miszczuk, 2021). It entails a reconfiguration of production-consumption systems, institutional arrangements, and socio-economic coordination mechanisms (Plotnic & Crudu, 2024). As such, the circular economy can be interpreted within the broader framework of sustainability transitions, where structural change unfolds through dynamic interactions between innovation niches, established regimes, and exogenous landscape pressures (Chizaryfard et al., 2021). The MLP provides a useful analytical lens for understanding these processes. Within this framework, landscape-level developments, such as climate change (Sipos et al., 2023), resource scarcity, and European Union policy commitments, exert pressure on dominant socio-technical regimes (F. Geels, 2024; Macher & Szigeti, 2025b). These regimes, composed of stabilised industrial structures, regulatory frameworks, and behavioural patterns, tend to resist radical transformation due to path dependencies and institutional lock-in (Kanger et al., 2020). Change often emerges through niche-level experimentation, where protected spaces allow novel technologies, governance models, and organisational forms to develop and mature. Transition occurs when landscape pressures destabilise regimes and niche innovations gain sufficient momentum to diffuse and reconfigure existing systems (Westley et al., 2011). While the MLP has been widely applied to national energy transitions and sectoral transformations (Pécsinger et al., 2025), its regional and cross-border governance dimensions remain comparatively underexplored (De Propriis & Bailey, 2021; Vähäkari et al., 2020). Regions are not merely passive arenas where transitions unfold; they are active sites of coordination, experimentation, and institutional learning (Grandin & Sareen, 2020). Industrial ecosystems, labour markets, innovation capacities, and policy competences are territorially embedded, making regional governance structures crucial in mediating between niche innovation and regime transformation (Song & Zhao, 2024). In this respect, meso-level institutional arrangements play a pivotal role in aligning actors, mobilising resources, and stabilising emerging practices (Battilana et al., 2009; Foulds et al., 2025).

Cross-border regions introduce additional complexity into transition processes. Administrative fragmentation, regulatory asymmetries, and uneven economic development can hinder coordinated sustainability strategies (Hu & Pikalo, 2025; Korhonen et al., 2021). At the same time, cross-border cooperation offers opportunities for complementary specialisation, shared infrastructure development, and knowledge exchange (Rammal et al., 2023). In this context, EGTCs constitute formalised governance frameworks designed to facilitate structured collaboration across national boundaries. Although primarily established to support territorial cohesion and project coordination, EGTCs may also provide institutional platforms for sustainability-oriented transformation (Evrard, 2016). Their hybrid nature, positioned between local, regional, and supranational governance levels, makes them particularly relevant for analysing multi-level transition dynamics (Topaloglou & Ioannidis, 2022; Yasmin et al., 2022). In this context, regional circular economy knowledge hubs can be conceptualised as potential transition intermediaries embedded within cross-border governance structures (Joltreau et al., 2025; Kern et al., 2020). Transition intermediaries are actors or platforms that facilitate interaction between niche innovators and regime actors, coordinate experimentation, and contribute to the diffusion and stabilisation of sustainable practices (Ehnert, 2023). When institutionally anchored within EGTC-based cooperation frameworks, knowledge hubs may enhance cross-border learning, reduce institutional fragmentation, and align regional development strategies with circular economy objectives (Eckardt & Gritsch, 2016). By integrating academic expertise, industrial experimentation, policy coordination, and stakeholder engagement, they can function as meso-level mechanisms that translate landscape pressures into territorially embedded transformation pathways (Jalonen & Uusikylä, 2025).

Despite the growing recognition of intermediaries in sustainability transitions, limited attention has been paid to their role in cross-border institutional settings (Kanda et al., 2020). The theoretical challenge lies in understanding how such hubs can simultaneously operate across governance scales, reconcile divergent regulatory environments, and contribute to regime reconfiguration without formal legislative authority (Jordana, 2017). Addressing this gap requires integrating transition theory with cross-border governance analysis, thereby extending the MLP framework towards a more territorially sensitive and institutionally nuanced perspective (Laur & Kanda, 2025).

By positioning regional circular economy knowledge hubs within EGTC-based cooperation structures, this paper advances the conceptualisation of meso-level institutional innovation in the green transition (Heurkens & Dąbrowski, 2020). It argues that such hubs may not merely support incremental innovation but can act as enabling infrastructures that mediate between niche experimentation and regional regime transformation, fostering resilience, inclusiveness, and long-term sustainability across European cross-border territories (Coenen et al., 2012; F. W. Geels, 2002).

3 Conceptual Framework

Building upon the MLP, this section develops a conceptual framework that positions regional circular economy knowledge hubs as cross-border transition intermediaries embedded within EGTC-based governance structures. Within the conventional MLP framework, niche innovations emerge in protected spaces, regimes stabilise dominant socio-technical configurations, and landscape pressures destabilise existing systems (El Bilali, 2019; Figueira et al., 2025). However, the framework pays comparatively limited attention to the institutional mechanisms that facilitate interaction between niches and regimes at the regional scale, particularly in cross-border contexts where governance fragmentation and regulatory asymmetries prevail. This paper argues that regional circular economy knowledge hubs may function as structured meso-level infrastructures capable of mediating these interactions. Conceptually, the proposed model introduces an intermediate governance layer situated between niche experimentation and regime transformation, embedded within cross-border cooperation structures. In this configuration:

- Landscape pressures (EU Green Deal objectives, climate neutrality commitments, resource security concerns) generate transformation imperatives.
- Regional socio-technical regimes reflect territorially embedded industrial systems, regulatory traditions, and institutional arrangements.
- Circular economy niches consist of experimental business models, technological pilots, and collaborative innovation initiatives.

- EGTC-based governance structures provide formalised cross-border coordination platforms.
- Regional circular economy knowledge hubs operate within this cross-border governance field as transition intermediaries.

Unlike isolated innovation clusters, knowledge hubs are conceptualised here as institutionalised coordination mechanisms with four interrelated functions:

- Alignment function: synchronising policy frameworks, regional development strategies, and industrial priorities across borders.
- Translation function: converting landscape-level sustainability objectives into regionally operationalised initiatives.
- Stabilisation function: supporting the institutional embedding and scaling of niche innovations within existing regimes.
- Learning and diffusion function: facilitating cross-border knowledge exchange and cumulative institutional learning.

In practical terms, these functions may include joint mapping of regional material flows, cross-border pilot coordination, shared training activities, and mechanisms for integrating successful experiments into EGTC development strategies. Through these functions, knowledge hubs may reduce institutional fragmentation, mitigate asymmetries between neighbouring regions, and enhance the resilience of circular transition pathways. Importantly, their transformative capacity does not derive from hierarchical authority but from their ability to coordinate, convene, and structure multi-actor collaboration across governance levels. The framework thus reconceptualises regional knowledge hubs as enabling infrastructures of sustainability transitions rather than as passive knowledge repositories. By embedding niche experimentation within cross-border governance architectures, they may create semi-protected institutional environments that both shield emerging practices and expose them to regime-level actors, facilitating gradual structural reconfiguration. Based on this conceptualisation, the following theoretical propositions are advanced:

- Proposition 1: The effectiveness of regional circular economy knowledge hubs increases when they are institutionally embedded within formalised cross-border governance structures such as EGTCs.
- Proposition 2: Knowledge hubs enhance the stabilisation and diffusion of circular economy niche innovations by performing alignment and translation functions between landscape pressures and regional regimes.
- Proposition 3: In cross-border contexts characterised by institutional asymmetry, knowledge hubs mitigate governance fragmentation by facilitating structured multi-level coordination.
- Proposition 4: The long-term transformative impact of knowledge hubs depends on their capacity to institutionalise learning processes and integrate circular practices into regional development strategies.

These propositions extend the MLP by introducing a territorially grounded meso-level intermediary concept specific to cross-border sustainability governance. The model highlights that transition processes in European border regions are not solely driven by technological breakthroughs or top-down policy shifts, but also by the institutional quality of coordination mechanisms capable of linking experimentation with structural change.

4 Discussion

The conceptualisation of regional circular economy knowledge hubs as cross-border transition intermediaries has several theoretical and governance-related implications. First, it refines the application of the MLP by foregrounding the importance of territorially embedded meso-level coordination mechanisms in sustainability transitions. Rather than viewing regime transformation as the outcome of niche momentum combined with landscape destabilisation, the framework highlights the institutional infrastructures that condition whether such interactions become stabilised and scalable. In cross-border contexts, transition dynamics are shaped not only by technological innovation and policy ambition but also by institutional asymmetry and administrative fragmentation (Miörner et al., 2018). Border regions frequently operate under divergent regulatory systems, funding mechanisms, and strategic priorities. These structural differences can slow down or even inhibit the diffusion of circular economy practices. By operating within structured cooperation

platforms such as EGTCs, regional knowledge hubs may create a semi-integrated governance field capable of mitigating these asymmetries without requiring full institutional harmonisation (Arsova et al., 2022; Kruse & Wedemeier, 2023). This suggests that transition processes in border regions are mediated by the quality of coordination rather than by formal authority alone.

Second, the framework shifts the analytical focus from isolated innovation projects towards systemic alignment processes. Circular economy experimentation often remains confined to pilot initiatives or sector-specific collaborations (Webster & Pascucci, 2024). Without institutional embedding, such initiatives risk remaining marginal. Knowledge hubs, when strategically positioned within cross-border governance structures, may facilitate cumulative learning and policy coherence, thereby increasing the likelihood that niche practices influence regime-level configurations (Bui et al., 2016; Concilio et al., 2023). In this sense, their role extends beyond knowledge dissemination, they function as translation mechanisms that convert abstract sustainability objectives into territorially operational strategies. Illustrative applications may include joint circular pilot projects, shared regional training programmes, or cross-border industrial symbiosis initiatives coordinated within EGTC-based cooperation frameworks. Third, the model underscores the relational nature of resilience in cross-border green transitions. Resilience is not merely the capacity to withstand external shocks, but the ability to adapt through coordinated institutional learning (Biesbroek et al., 2017; Han et al., 2025). Knowledge hubs may enhance adaptive capacity by structuring multi-actor dialogue, fostering trust across borders, and integrating industrial experimentation into regional development agendas. This relational resilience is particularly relevant in European border regions facing economic disparities, demographic challenges, and uneven industrial specialisation (Ezcurra & Rios, 2019).

At the same time, the transformative potential of such hubs should not be overstated. Their effectiveness depends on stable funding mechanisms, political commitment, stakeholder engagement, and the ability to maintain legitimacy across administrative systems. Without sufficient institutional embedding, knowledge hubs risk functioning as project-based networks with limited structural impact (Pantiris et al., 2025; Tumpa & Naeni, 2025). Moreover, power asymmetries between neighbouring regions may influence agenda-setting processes, potentially reproducing existing development imbalances rather than mitigating them. The

discussion therefore points to a broader theoretical insight, sustainability transitions in cross-border regions require intermediary infrastructures capable of navigating institutional plurality. By conceptualising regional circular economy knowledge hubs as structured coordination mechanisms embedded in EGTC-based cooperation, this paper contributes to a more territorially sensitive interpretation of transition theory. It emphasises that the green transition in European border regions is not solely a matter of technological diffusion or regulatory reform, but also of institutional design and cross-border governance capacity. It situates regional circular economy knowledge hubs as potential enabling infrastructures of the green transition, capable of bridging niche experimentation and regional socio-technical regimes within complex cross-border governance environments.

5 Conclusions

The analysis presented in this paper suggests that regional circular economy knowledge hubs may represent a strategically significant yet currently underutilised governance instrument in advancing the green transition within cross-border regions. By conceptualising these hubs as transition intermediaries embedded in EGTC-based cooperation frameworks, the paper has extended the MLP towards a more territorially grounded and institutionally nuanced understanding of sustainability transformation. Knowledge hubs cannot function effectively as transformative intermediaries if they remain project-based or loosely coordinated networks. Their stabilising and alignment capacities depend on formal anchoring within cross-border governance architectures, predictable funding mechanisms, and clearly defined mandates. Policymakers should therefore prioritise integrating circular economy knowledge infrastructures into existing EGTC cooperation strategies rather than treating them as auxiliary innovation platforms.

Cross-border coordination requires structured translation mechanisms. Landscape-level sustainability objectives, such as climate neutrality, resource efficiency, and circular industrial policy, must be operationalised in ways that reflect regional industrial structures and socio-economic asymmetries. Knowledge hubs can perform this translation role by aligning regional development strategies, facilitating joint experimentation, and creating shared strategic narratives across administrative boundaries. Policy instruments should support these alignment processes through multi-level coordination schemes and dedicated cross-border funding streams. The

long-term transition capacity depends on institutionalised learning. Circular economy transformation is inherently iterative and path-dependent. Knowledge hubs may enhance regional resilience not simply by disseminating technical expertise but by embedding continuous learning, evaluation, and feedback mechanisms into cross-border governance structures. This requires sustained stakeholder engagement, transparency in decision-making processes, and mechanisms to integrate experimental outcomes into mainstream regional policy frameworks.

At the same time, several structural constraints must be acknowledged. Institutional fragmentation, uneven resource distribution, and political discontinuities may limit the effectiveness of cross-border knowledge infrastructures. Without strategic coordination, hubs risk reinforcing existing asymmetries between neighbouring regions rather than mitigating them. Furthermore, the absence of regulatory harmonisation may constrain scaling processes, even when collaborative platforms are present. These challenges underscore the need for carefully designed governance architectures that balance flexibility with institutional stability.

This paper contributes to sustainability transition research by introducing the concept of the cross-border transition intermediary as a meso-level institutional mechanism within the MLP. It highlights that regime transformation in European border regions is mediated not only by technological innovation and macro-level policy pressures but also by the quality of territorially embedded coordination infrastructures. By integrating transition theory with cross-border governance analysis, the paper advances a more spatially sensitive interpretation of circular economy transformation. Although largely conceptual, the proposed framework provides a foundation for future empirical research. Comparative case studies of EGTC-based cooperation structures, network analyses of stakeholder interactions, and longitudinal assessments of circular innovation scaling could further test and refine the propositions advanced here. Such investigations would deepen the understanding of how institutional design influences transition outcomes across diverse European territories.

Regional circular economy knowledge hubs have the potential to function as enabling infrastructures of the green transition in cross-border contexts. Their transformative capacity lies not in hierarchical authority, but in their ability to coordinate, align, and stabilise emerging circular practices within fragmented

governance environments. If strategically embedded and adequately supported, they may contribute to the development of resilient, inclusive, and territorially anchored circular economy pathways across European border regions.

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URBAN SUSTAINABILITY TRANSITIONS TOWARDS ASBESTOS-FREE MUNICIPALITIES

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The phase-out of asbestos in urban environments represents a complex challenge across European municipalities. Despite European Union targets to achieve asbestos-free cities, implementation remains uneven because municipalities face fragmented regulations, differing inspection and disclosure requirements, limited funding, technical constraints, and variable public awareness. The paper identifies key barriers, including regulatory heterogeneity, inadequate disposal infrastructure, and financing gaps, as well as enabling factors such as harmonized policies, innovative treatment technologies, capacity-building programs, and community engagement. Based on these insights, a typology of municipal transition pathways is developed, including compliance-driven, retrofit-integrated, innovation-led, community-driven, and market-based approaches. The findings also underline equity considerations, emphasizing the need to prevent disadvantaged communities from remaining disproportionately exposed to asbestos hazards. By framing asbestos removal as a material legacy transition within broader urban sustainability transitions, the paper contributes both to theoretical understanding of socio-technical and ecosystem dynamics and to practical guidance for policymakers and urban planners.

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1 Introduction

Asbestos remains one of the most persistent environmental and public health hazards in European cities, despite longstanding bans on its use (Curado et al., 2024). Its widespread application in historical construction has left a legacy of ageing buildings and infrastructure containing asbestos-containing materials (abbreviation: ACMs) that continue to pose risks when deteriorated or improperly removed (Butkevics & Atstaja, 2025). Exposure to asbestos is linked to serious diseases, including mesothelioma, lung cancer, and asbestosis, often decades after initial contact (Klebe et al., 2024). While the European Union has set an ambitious target for asbestos-free cities by 2032, progress across municipalities remains uneven because rules on asbestos inspection, disclosure during property transactions, removal obligations, financing eligibility, and waste handling differ across jurisdictions, while limited financing, insufficient technical capacity, and low public awareness further constrain implementation. Local contexts (such as institutional capacity, economic resources, public attitudes, and existing infrastructure) significantly influence the pace and effectiveness of removal programs (Vincenten et al., 2017).

Current research often focuses on technical removal methods, waste management, or health risks, but less attention has been paid to treating asbestos elimination as a systemic urban sustainability transition (Durczak et al., 2024). Cities function as complex urban ecosystems (Bódizs et al., 2025), where infrastructure, institutions, and communities interact to shape both environmental risks and sustainability transitions. This paper addresses this gap by applying a systemic ecosystem framework that integrates institutional, technological, economic, social, and infrastructural dimensions to analyse municipal asbestos phase-out. The research identifies barriers and enablers, maps distinct transition pathways, and examines how path dependencies shape implementation strategies. By combining theoretical insights from sustainability transitions with comparative observations drawn from policy documents, regulatory frameworks, municipal strategies, and academic literature on European municipalities, it provides actionable guidance for policymakers, urban planners, and industry stakeholders. The paper positions asbestos removal not only as a technical or regulatory task, but as a multidimensional challenge central to achieving sustainable, resilient, and equitable urban futures.

2 Theoretical Background

Sustainability transitions research aims to understand how complex socio-technical systems evolve toward more sustainable configurations involving intertwined technological, institutional, economic, and social change processes (Andersson et al., 2024). A dominant analytical lens in this field is the Multi-Level Perspective (abbreviation: MLP), which conceptualizes transitions as emerging from dynamic interactions among niches (protected spaces for innovation), regimes (stable configurations of institutions, practices, and technologies), and landscape pressures (broad socio-economic and cultural forces) that together enable or impede systemic change (F. W. Geels, 2011). Traditionally, MLP has been applied to energy, transport, and resource systems, revealing how novelty emerges in sheltered spaces, destabilizes incumbent regimes under external pressures, and eventually reshapes socio-technical configurations (F. Geels, 2024). However, sustainability transitions research increasingly recognizes that meaningful transformation often requires governance and institutional change (Nagy-Rádli et al., 2025), addressing entrenched path dependencies and lock-in effects that are not reducible to technological innovation alone (van Wijk & Fischhendler, 2025). Complementing MLP, innovation ecosystem thinking emphasizes the systemic interdependencies among heterogeneous actors, funding flows, organizational networks, and enabling institutions, enabling a richer understanding of how transition processes unfold across multiple domains beyond individual technologies or policies (Sultana & Turkina, 2023).

This perspective highlights that transitions emerge not only from niche innovations but also from co-evolutionary processes that involve learning, collaboration, and coordination among diverse stakeholders (Winkler-Portmann et al., 2025). In parallel, institutional theory contributes insights into how regulatory capacity, governance norms, and policy frameworks shape actors' capabilities to enact change (Brammer et al., 2012). Institutional arrangements influence both the distribution of authority and the allocation of resources necessary to support systemic transition processes, including regulatory harmonization, enforcement mechanisms, and mechanism design for equitable cost sharing (Radtke & Renn, 2024). This paper treats asbestos phase-out as a material-legacy transition, a form of sustainability transition that is driven by decommissioning and remediation of hazardous infrastructures rather than only by the diffusion of environmentally beneficial

technologies. The integrated ecosystem framework developed here captures cross-domain interactions among institutional, technological, economic, social, and infrastructural elements, providing a holistic lens to analyse how municipal actors negotiate barriers and harness enabling conditions for urban sustainability transitions.

To synthesize the theoretical perspectives discussed above, Figure 1 applies the multi-level perspective to municipal asbestos phase-out as a material legacy transition. The figure illustrates how landscape-level pressures, including public health imperatives and EU policy targets, interact with regime-level municipal governance structures, infrastructure systems, and regulatory frameworks. At the niche level, emerging removal technologies, pilot projects, and innovative governance arrangements create protected spaces for experimentation and learning. The framework highlights that transition dynamics are driven not by technological diffusion alone, but by the coordinated reconfiguration of institutional, economic, technological, and social elements. More specifically, institutional rules shape which technologies can be adopted and financed, while social acceptance, contractor capabilities, and public communication influence whether removal programmes are implemented effectively. This conceptualization provides the analytical foundation for the methodological approach and comparative analysis presented in the following sections.

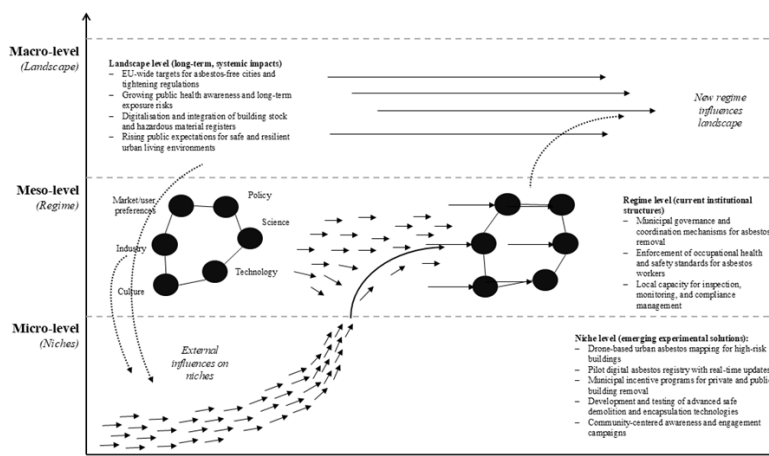


Figure 1: Multi-level perspective applied to municipal asbestos phase-out
Source: author's own elaboration.

3 Methodology and Research Design

This paper adopts a qualitative, comparative research design to examine asbestos phase-out as an urban sustainability transition at the municipal level in Europe. Municipalities are selected as the unit of analysis because they represent the primary arena where regulatory implementation, infrastructure management, and public engagement intersect. The analysis focuses on European urban contexts in which asbestos use is banned, but significant legacy stocks of asbestos-containing materials remain.

The paper applies an ecosystem-based analytical framework integrating institutional, technological, economic, social, and infrastructural dimensions. Data sources include policy documents, regulatory frameworks, municipal strategies, and peer-reviewed academic literature that document recurring implementation conditions, governance arrangements, and removal challenges across European municipalities. These materials are analysed using qualitative content analysis, combining deductive coding informed by sustainability transition theory with inductive identification of emergent patterns, illustrative implementation scenarios, and recurring cross-case mechanisms. A comparative logic is employed to identify recurring transition pathways across municipalities while accounting for local contextual variation; rather than presenting full case studies, the paper synthesizes recurring patterns reported across European contexts. The research emphasizes analytical rather than statistical generalization, focusing on mechanisms and configurations shaping removal outcomes. Limitations include uneven data availability and reliance on secondary sources, which are mitigated by a focus on cross-case patterns and systemic insights.

4 Results and Discussion

The results demonstrate that achieving asbestos-free urban environments is not primarily a technical challenge but a systemic governance issue that unfolds across multiple interacting domains. Municipal progress depends on the coordinated alignment of institutional frameworks, financial instruments, technological capacities, social engagement, and infrastructural conditions. Isolated policy measures or technological solutions are insufficient to trigger sustained removal dynamics. Instead, effective implementation emerges where multiple levers are activated simultaneously within a coherent policy mix.

Institutional arrangements appear as the most influential factor shaping municipal asbestos phase-out trajectories. Municipalities with clear allocation of responsibilities, standardized asbestos registries, and enforcement capacity are better positioned to plan, prioritize, and sequence removal activities. Registries function not only as technical tools but also as governance instruments that enhance transparency, enable targeted financing, and support risk-based prioritization. In this context, fragmented regulations refer to situations in which inspection duties, disclosure requirements in property transactions, financing eligibility, and waste-management procedures are distributed unevenly across administrative levels or jurisdictions. For example, one municipality may require an asbestos assessment before renovation or sale, while another may rely mainly on general construction compliance, leading to markedly different implementation pathways. Incomplete data systems and fragmented competencies therefore generate inertia even in contexts with formal regulatory bans.

Economic constraints constitute a second major barrier. Asbestos removal, transport, and disposal remain significantly more expensive than conventional renovation activities, placing a disproportionate burden on municipalities and low-income households. A retrofit-integrated pathway refers to situations in which asbestos removal is embedded in broader building renovation, energy-efficiency upgrading, or urban regeneration programmes, allowing municipalities and property owners to combine funding streams, administrative procedures, and construction works. In such cases, implementation can accelerate through cost-sharing and administrative synergies. However, without explicit equity mechanisms, such integrated approaches risk privileging better-resourced property owners.

Technological capacity forms a third critical axis. Conventional manual removal and controlled landfill disposal remain the dominant practices, yet they generate large volumes of hazardous waste and long-term disposal liabilities. Emerging alternatives offer potential pathways to reduce landfill dependence and support circular economy objectives. From a transition perspective, these technologies operate as experimental niches rather than immediate substitutes, with their diffusion contingent upon regulatory adaptation, risk governance, and public acceptance. Municipalities can play an active role as niche sponsors by enabling pilot projects, facilitating learning, and negotiating regulatory flexibility.

Social dynamics significantly influence compliance and legitimacy. Municipalities that invest in public awareness campaigns, contractor training, and transparent communication experience lower rates of illegal disposal and higher participation in removal programs. Infrastructural legacies and path dependencies further shape implementation strategies. Concentrated asbestos stocks in public buildings enable economies of scale, while diffuse private holdings require mass inspection, subsidy schemes, and long-term engagement strategies. Sequencing approaches that prioritize high-risk public assets and use them as demonstration projects have proven effective in building capacity and trust, thereby catalysing broader private-sector uptake.

These findings reveal distinct municipal transition pathways, ranging from compliance-driven strategies to retrofit-integrated, innovation-led, community-driven, and market-based approaches. These pathways emerge from different combinations of institutional capacity, technological readiness, financing arrangements, and social engagement rather than from a single policy instrument or technological solution. These pathways differ in speed, equity, and scalability, highlighting that no single model is universally optimal. Rather, asbestos phase-out success depends on adaptive governance capable of aligning institutional, economic, technological, and social dimensions in response to local conditions. The results reinforce broader sustainability transition insights emphasizing policy coherence, learning-oriented implementation, and the strategic management of material legacies.

The research provides actionable insights for municipal policymakers. Effective asbestos phase-out requires multi-domain coordination, aligning regulatory enforcement, dedicated funding, and technical capacity to accelerate removal outcomes. Transparent asbestos registries, as promoted in EU guidance and national frameworks, are critical for identifying high-risk buildings, planning interventions, and building public trust. Funding mechanisms should ensure equitable access; combining asbestos removal with EU-supported renovation or energy-efficiency programs can reduce costs while avoiding exclusion of vulnerable populations. Sequencing interventions by prioritizing public assets such as schools and hospitals helps build technical capacity and encourages subsequent private-sector uptake. Pilot projects for advanced technologies, including thermal treatment, vitrification, or chemical stabilization, enable learning and regulatory adaptation. Integrating removal with urban regeneration or energy retrofits generates co-benefits and

reduces administrative burdens. Participatory approaches that involve communities and contractors improve compliance, trust, and long-term sustainability. Altogether, these lessons emphasize that effective asbestos phase-out requires adaptive, learning-oriented governance that balances technical feasibility, social equity, and institutional capacity.

5 Conclusions

This paper demonstrates that asbestos phase-out in European municipalities represents a complex sustainability transition requiring coordinated action across multiple domains. Effective removal depends on the alignment of institutional arrangements, financing mechanisms, technological capacities, social engagement, and infrastructural management. Municipalities adopt distinct transition pathways (compliance-driven, retrofit-integrated, innovation-led, community-driven, and market-based), each with differing speed, equity, and scalability. Early interventions in high-risk public assets build technical capacity, reduce perceived risk, and catalyze broader participation in private housing programs. Municipalities that support pilot projects for advanced treatment technologies facilitate safe, innovative, and circular approaches to asbestos management.

Policy packages combining harmonized regulation, dedicated funding, transparent registries, and community engagement consistently outperform isolated measures. Equity considerations are central, ensuring vulnerable populations are not disproportionately exposed. Demonstration projects, capacity-building initiatives, and public awareness campaigns strengthen compliance and long-term program success. The paper provides both theoretical contributions to sustainability transition research and practical guidance for urban governance, highlighting the need for integrated, adaptive, and socially responsive strategies to achieve asbestos-free urban futures.

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AI ANXIETY AND WORKFORCE RESILIENCE THROUGH ESG SOCIAL RESPONSIBILITY AND ADULT EDUCATION

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The rapid integration of Artificial Intelligence (abbreviation: AI) is driving a profound industrial transformation, yet it simultaneously generates considerable anxiety among employees, posing risks to sustainable organizational performance. This paper examines AI-related anxiety within the Hungarian labour market and explores mitigation strategies through the lens of the ESG Social pillar. Adopting a mixed-method approach, combining online surveys to assess learning self-efficacy with qualitative interviews, the research investigates the intersection of technological disruption and human capital management. Findings demonstrate that psychological safety and targeted adult education function not merely as HR instruments but as essential governance mechanisms. Moreover, the data highlight that transparent communication regarding AI deployment alleviates uncertainty and fosters a resilient organizational climate conducive to continuous innovation. The paper argues that navigating AI transformation successfully requires a paradigm shift in management. Sustainable governance must prioritize the human dimension by cultivating trust-based environments.

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1 Introduction

Artificial Intelligence (abbreviation: AI) is rapidly transforming the contemporary world, exerting a dual impact on economic and social processes. While the technology promises increased productivity and accelerated innovation, it simultaneously generates uncertainty and anxiety among employees. The aim of this paper is to examine how psychological safety and adult education, key components of the Social (“S”) pillar of the ESG framework, can mitigate AI-related anxiety and support successful adaptation. According to the OECD (2023), AI is defined as an adaptive system capable of autonomously deriving inferences from input data. This capability distinguishes AI from traditional automation and enables it not only to replace routine tasks but also to transform processes requiring complex problem-solving (Autor et al., 2003). The Future of Jobs Report 2025 indicates that technological advancement and the green transition will radically reshape skill requirements between 2025 and 2030 (World Economic Forum, 2025). Although macroeconomic evidence, such as analyses by the Yale Budget Lab and the Brookings Institution (2025), suggests relative stability in employment indicators, subjective social perceptions reveal an opposing trend. A survey by the Pew Research Center (2025) shows that 52% of employees report greater concern than optimism, while data from the European Commission (2025) indicate that trust in technology is conditional and closely linked to transparency.

This uncertainty underpins the phenomenon of AI anxiety, which the literature conceptualizes as a multidimensional construct encompassing job replacement anxiety, AI learning anxiety, and ethical concerns. The empirical scale developed by Wang and Wang (2022), the AI Anxiety Scale (AIAS), demonstrates that this form of anxiety is objectively measurable and negatively affects technology acceptance. Empirical evidence further suggests that employees experience heightened anxiety when AI is perceived as a threat, whereas higher levels of learning self-efficacy function as a protective factor (Li et al., 2024). One of the most effective antidotes to technological anxiety can be found in organizational culture, particularly in the presence of psychological safety. According to Edmondson’s conceptualization (1999, 2018), psychological safety refers to a shared belief that it is safe to take interpersonal risks, make mistakes, and ask questions within a group. During AI integration, where learning curves are steep and errors constitute a natural part of the process, such an environment becomes critically important. Research by

Martínez-Córcoles et al. (2024) highlights the mediating role of psychological safety: in its absence, employees tend to avoid using new technologies, whereas its presence increases innovative behaviour and reduces resistance to change. In this paper, AI-related anxiety is used as the primary term. It refers to employees' concerns, uncertainty, perceived vulnerability, and perceived threat associated with the introduction and use of artificial intelligence in the workplace. Related expressions such as technological anxiety or fear of AI are treated as overlapping concepts in the literature, but the analysis consistently uses AI-related anxiety as the central concept.

However, the success of technological adaptation is determined not only at the organizational level but also at the individual level, where adult education, through upskilling and reskilling, emerges as a strategic instrument. According to Knowles' andragogical model and the concept of lifelong learning (abbreviation: LLL), adult learning is primarily driven by intrinsic motivation and practical applicability. This issue is closely aligned with the S-pillar of the ESG framework (Nagy-Rádlí et al., 2025). In accordance with the EU's Corporate Sustainability Reporting Directive (abbreviation: CSRD) and the Hungarian ESG Act (Act CVIII of 2023), employee training and well-being are no longer merely HR concerns but constitute sustainability obligations. Inclusive training programs reduce digital divides and social inequalities (OECD, 2025) while simultaneously enhancing organizational resilience. Psychological safety and targeted skill development thus jointly form a protective framework capable of transforming AI-related anxiety into constructive adaptation.

The contribution of this paper lies in connecting AI-related anxiety, workforce resilience, ESG social responsibility, psychological safety, and adult education within one empirical framework. While previous research has often examined technological anxiety, workplace learning, or organizational responsibility separately, this paper focuses on how these dimensions interact in the context of AI-driven transformation. The Hungarian labour market context provides additional empirical value, as it shows how employees perceive AI-related risks and learning opportunities in a specific Central and Eastern European setting.

2 Research Objectives and Methodology

The primary objective of the research is to explore the extent to which AI-related anxiety is present among Hungarian employees and to examine how psychological safety and adult education can mitigate this phenomenon. The paper formulates three hypotheses.

- First, it is assumed that a significant proportion of respondents (at least 50%) experience measurable levels of technological anxiety (H1).
- Second, it is hypothesized that higher levels of psychological safety are positively correlated with learning self-efficacy (H2).
- Third, the research investigates the assumption that participation in adult education, whether in the form of upskilling or reskilling, significantly reduces fear and enhances adaptive capacity (H3).

To address these objectives, the paper employs a mixed-methods research design, integrating quantitative and qualitative approaches to achieve both comprehensive coverage and in-depth understanding. Data collection is primarily based on an anonymous online questionnaire using validated measurement scales to assess AI-related fears, perceived workplace psychological safety (e.g., freedom to make mistakes and ask questions), and learning self-efficacy. In the empirical analysis, upskilling and reskilling were treated as a combined adult education category. The purpose of the study was to examine employees' general participation in and perceived need for work-related learning opportunities, rather than to compare different forms of training separately. This is acknowledged as a limitation, since future research could investigate whether upskilling and reskilling have different effects on AI-related anxiety and workforce resilience. As the questionnaire was based on previously validated measurement scales, construct validity was supported by the existing literature. However, the absence of a separate reliability analysis for the present sample is acknowledged as a limitation of the study. Sampling was conducted using convenience and snowball techniques. The target population consisted of Hungarian employees, and the final sample included 239 respondents. Participants were eligible for inclusion if they were employed adults in Hungary and had direct or indirect exposure to digital transformation or AI-related changes in the workplace. The sample was not restricted to one specific industry, as the aim of the

study was to capture broader labour market perceptions rather than sector-specific effects. Therefore, the findings should be interpreted as exploratory and context-sensitive rather than fully representative of the Hungarian labour market.

Quantitative data were analysed using descriptive statistics, correlation analysis, and group comparison tests. To contextualize and deepen the interpretation of numerical findings, the research was supplemented with a qualitative component consisting of up to six semi-structured interviews. These interviews enabled the exploration of individual motivations and psychological mechanisms underlying the statistical patterns. The qualitative interview material was analysed using thematic analysis. The coding process followed a primarily inductive logic, allowing themes to emerge from the interview data, while the interpretation was informed by the study's conceptual focus on AI-related anxiety, psychological safety, ESG social responsibility, and adult education. The entire research process adhered to strict ethical standards, ensuring voluntary participation and full anonymity of all respondents.

3 Results

During the empirical phase of the paper, 239 Hungarian employees of diverse ages and occupational backgrounds participated, providing a comprehensive overview of labour market attitudes toward AI. The combined analysis of quantitative data and qualitative interview insights confirmed that technological transition constitutes not merely a technical challenge but a deeply psychological and sociological issue. The primary finding of the paper is that AI-related anxiety is markedly present in the Hungarian labour market, thereby confirming the first hypothesis (H1). More than half of the respondents (52.7%) reported moderate to high levels of fear. Specifically, 33.9% indicated that they fully feared, while 18.8% reported that they were rather concerned about the possibility that new technologies could threaten their jobs in the future. However, the distribution of anxiety is uneven and follows distinct demographic patterns. Gender-based analysis revealed a notable paradox: while women reported a lower sense of existential threat (23.6%), the proportion was significantly higher among men, reaching 49%. This phenomenon may be explained by the higher concentration of men in technical or industrial sectors where automation and efficiency gains are perceived as direct job-related risks.

A similarly revealing pattern emerged in relation to age, where the data displayed a characteristic U-shaped distribution. Anxiety levels were highest among early-career employees (aged 18–34) and those approaching retirement (aged 55 and above), whereas experienced workers aged 35–54 formed the most stable and least anxious group. This suggests that professional experience and labour market stability function as protective factors, while employees at the beginning and end of their careers perceive themselves as more vulnerable to change. The descriptive results suggest a negative relationship between educational attainment and AI-related anxiety. Respondents with tertiary education largely did not perceive AI as a threat, whereas those with secondary education reported the highest anxiety levels. This finding supports the assumption that workers engaged in routine administrative or manual tasks perceive automation risks more acutely.

The intensity of fear was also closely linked to technological exposure and usage routines. Forty-four percent of respondents reported that some form of AI solution was already in use at their workplace. The data clearly indicate that perceived competence reduces anxiety. The highest levels of fear were observed among employees who possessed partial knowledge but lacked confidence in using AI tools. This group, referred to as “uncertain users”, experiences heightened vulnerability due to perceived knowledge gaps. In contrast, active and proficient users reported significantly lower anxiety levels, reinforcing the conclusion that technological literacy itself has an anxiety-reducing effect. However, the success of technological adaptation depends not only on individual competencies but also on organizational culture. The second hypothesis (H2) focused on the role of psychological safety. While three-quarters of respondents (75%) generally perceived their workplace as safe in terms of asking questions and making mistakes, one quarter did not experience such a supportive environment. Particularly concerning is the finding that 33% of respondents did not perceive managerial support for experimentation, and nearly 24% reported that they were reluctant to seek help when facing technological difficulties. Statistical analysis revealed that the absence of psychological safety inhibits innovation-related adaptation: employees who do not feel safe are more likely to perceive AI implementation as a threat and are less open to acquiring new skills.

The most encouraging findings emerged in relation to the third hypothesis (H3), which examined the role of adult education. Results indicate that Hungarian employees exhibit a high willingness to learn. Seventy-nine percent of respondents agreed that well-structured training programs would reduce their fears, while 82% believed that training focused on practical application would alleviate feelings of vulnerability. Analysis of training motivation revealed unexpected demographic patterns. On a five-point scale, respondents with primary education demonstrated the highest learning motivation (mean = 4.50), suggesting that the most vulnerable group perceives learning as the primary means of labour market survival and upward mobility. Equally noteworthy is the attitude of employees aged over 55, whose learning motivation (mean = 3.70) was only slightly lower than that of middle-aged respondents and exceeded that of the youngest cohort. This finding challenges the stereotype that older workers resist new technologies. For this group, training represents a means of maintaining professional relevance. These statistical findings were further enriched by the qualitative interviews conducted during the second phase of the research. The interviews confirmed that AI-related anxiety is not a homogeneous phenomenon but is strongly shaped by professional identity and life circumstances. Digitally mature younger employees, such as Milan, one of the interviewees, approached AI pragmatically, viewing it as a functional work tool without anxiety. In contrast, professionals in human-centred fields, such as Erika (a teacher) and Júlia (a healthcare administrator), expressed concerns not about the technology itself but about dehumanization and the blurring of responsibility. In their cases, anxiety was primarily ethical in nature, centred on the question of how the human element can be preserved in care-oriented professions. A third type of anxiety was illustrated by Zoltán, a middle manager, whose concerns stemmed from performance pressure and time constraints. One of the most important insights from the interviews is that employees are generally willing to engage in learning, but the lack of organizational support and dedicated learning time often constitutes a significant barrier. As Júlia noted, “*Knowledge is always reassuring, especially when people’s health is at stake*” highlighting that relevant and well-designed training not only enhances competence but also fosters psychological safety.

The findings demonstrate that while AI-related anxiety is a real and widespread phenomenon in the Hungarian labour market, it does not constitute an insurmountable obstacle. High learning motivation and a strong demand for psychological safety clearly identify the key intervention points. The success of

technological transition depends not on algorithms alone but on human-centred leadership and targeted, supportive adult education programs.

4 Discussion and Recommendations

Based on the synthesis of quantitative survey data and in-depth interviews, the research identified three core problem areas that directly correspond to the study's hypotheses: the nature of AI-related anxiety (H1), the lack of psychological safety (H2), and the inadequacy of current adult education practices (H3). Addressing these challenges extends beyond the scope of human resource management and constitutes a strategic issue within the Social ("S") pillar of the ESG framework.

The primary problem is that AI-related anxiety, affecting more than half of employees (52%), does not stem solely from a lack of technological knowledge but rather from deeper uncertainties related to professional identity and responsibility. As highlighted in the interviews, such as those with Erika, a teacher, and Júlia, a healthcare administrator, fear is often not focused on job loss per se but on the erosion of professional roles and the loss of control over decision-making processes. In contrast, technologically mature employees exhibited minimal anxiety, largely due to clearly defined professional boundaries and responsibilities. Consequently, the key intervention lies in transparent organizational communication. During AI implementation, it is insufficient to focus solely on the "how"; organizations must also explicitly address the "why" and clarify issues of accountability and responsibility. Demystifying technology and clearly delineating human decision-making authority can significantly reduce perceptions of existential threat.

The second critical issue concerns the strong correlation between psychological safety and learning self-efficacy. The research confirms that access to technology alone is insufficient if organizational culture does not support experimentation, error-making, and inquiry. Insecure employees, such as Réka or Zoltán, a middle manager, often refrain from learning because they fear that asking questions signals incompetence. This latent anxiety inhibits innovation-related adaptation. The recommended intervention is the deliberate cultivation of psychological safety through the creation of learning-oriented environments (internal workshops or "failure-sharing" events), where mistakes are framed as integral components of the learning process rather than as punishable shortcomings. Leadership plays a decisive

role in this regard: managers are uniquely positioned to establish the trust-based climate in which technological change is perceived not as a threat but as a shared developmental journey.

Finally, current adult education practices frequently fail to align with employee needs. Although learning motivation is high (71%), it becomes activated only when training is relevant, context-specific, and practice-oriented. Instead of standardized, generic AI education programs, organizations require targeted, role-specific training initiatives, for example, data security training for administrative staff or AI-supported pedagogical methodologies for educators. Importantly, training programs should not focus exclusively on technical competencies but should also support the redefinition of professional identity within increasingly automated work environments.

From a systemic perspective, these challenges necessitate the alignment of institutional, policy, and societal responsibilities. Beyond fulfilling ESG reporting obligations under the CSRD, companies must elevate employee well-being and education into core strategic priorities. At the policy level, inclusive digital upskilling initiatives should be actively promoted, particularly for technologically vulnerable groups such as older workers and individuals with lower levels of formal education. Only through such coordinated efforts can AI integration avoid exacerbating social inequalities and instead, through psychological safety and knowledge empowerment, contribute to a more sustainable and human-centred labour market.

Based on the findings, a three-step human-centred AI transition framework can be proposed. First, organizations should reduce uncertainty through transparent communication about the purpose, scope, and responsibility structures of AI use. Second, they should strengthen psychological safety by encouraging questions, experimentation, and open discussion of mistakes. Third, they should provide targeted adult education that is role-specific, practice-oriented, and accessible to vulnerable employee groups. Together, these measures connect AI implementation with the Social pillar of ESG by protecting employee well-being, employability, and organizational resilience.

5 Conclusions

The findings of this study demonstrate that AI integration represents not merely a technological adaptation challenge but a fundamental issue of human strategy and sustainability, directly linked to organizational social responsibility within the ESG framework. The empirical results corroborate trends identified in the international literature while also refining them within the Hungarian context. The identification of anxiety among more than half of respondents supports Wang and Wang's (2022) conceptualization of AI anxiety as a multidimensional construct, encompassing not only job replacement anxiety but also learning-related anxiety. Particularly instructive is the strong negative correlation between educational attainment and anxiety levels, which reinforces the OECD's (2023) warning regarding the risk of widening digital divides. The data suggest that technological transition disproportionately affects the most vulnerable groups, those with lower educational attainment or limited technological maturity, thereby underscoring the urgency of systemic social intervention.

One of the most significant insights of the study concerns the decisive role of organizational culture. The findings reaffirm Edmondson's (1999, 2018) model of psychological safety by demonstrating that environments lacking support for error-making and open inquiry inhibit innovation-related adaptation. Employees who perceive their workplaces as unsafe tend to disengage from learning as a defensive mechanism, creating a self-reinforcing cycle that intensifies anxiety. Conversely, supportive leadership behaviour and transparent communication not only facilitate technology acceptance but also reinforce employees' professional identities amid continuous change. The strategic transformation of adult education emerges as a key solution. The research highlights that employees' willingness to learn is substantial, provided that training is relevant and practice-oriented, in line with Knowles' andragogical principles. However, technological training alone is insufficient. Effective development programs must integrate upskilling and reskilling with the deliberate cultivation of psychological safety. This integrated approach situates the issue squarely within the S-pillar of the ESG framework, as preserving employees' mental well-being and employability has become an essential prerequisite for corporate sustainability. In conclusion, the era of artificial intelligence does not signify the end of human work but rather its transformation. The successful integration of AI depends not on the sophistication of algorithms but on the support

of the human dimension. Organizations that recognize knowledge and trust as the primary antidotes to AI-related anxiety, and that succeed in creating workplace ecosystems where technology augments rather than replaces human capabilities, will be best positioned to achieve sustainable competitiveness and shared development.

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INTEGRATING THE SOCIAL DIMENSION OF ESG INTO CIRCULAR BUSINESS MODEL TRANSFORMATIONS

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The transition towards circular economy business models is increasingly framed as a key instrument for achieving environmental sustainability and long-term economic resilience. However, the social dimension of sustainability within circular transformations remains underexplored in both academic research and corporate practice, despite its growing relevance in ESG frameworks. This paper addresses this gap by examining how social sustainability can be embedded into circular business model transformations in order to generate social as well as environmental value. Furthermore, the paper explores stakeholder engagement mechanisms within circular value chains, focusing on the involvement of employees and local communities as key contributors to socially inclusive circular practices. Finally, the alignment between corporate governance structures and social sustainability objectives is analysed, highlighting how governance mechanisms can facilitate the integration of social considerations into circular strategies. The paper links circular business model innovation with ESG social performance, contributing to sustainability and management literature.

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1 Introduction

The circular economy (abbreviation: CE) has become a central paradigm in sustainability research, promising systemic improvements in resource efficiency and waste reduction beyond linear production models (Bódizs, 2022). However, despite the widespread adoption of CE principles, academic studies show that the social dimension of sustainability is much less explored in CE research compared to environmental and economic aspects (Velenturf & Purnell, 2021). Despite increasing corporate interest in Environmental, Social, and Governance (abbreviation: ESG) frameworks, firms' sustainability reporting still tends to prioritise environmental over social performance (Nagy-Rádli et al., 2025). Studies linking CE and ESG frameworks suggest that greater integration could enhance corporate accountability and sustainability performance, but emphasise that the relationship remains ambiguous in both theory and practice (Kopnina et al., 2025). Furthermore, stakeholder engagement has been identified as a key mechanism through which CE practices can be made socially responsive, but management literature has yet to systematically address how engagement influences sustainable value creation (Oberholzer & Sachs, 2023). Similarly, governance structures shape how organisations align circular strategies with broader social sustainability goals, but their role remains surprisingly underexplored in CE research (Al-Najjar et al., 2025). This paper aims to address this gap by developing a conceptual framework that explicitly integrates social sustainability into circular business model transformations. Against this backdrop, there is a clear need for conceptual work that bridges CE business model transformations and the ESG social pillar, making explicit how circular strategies can generate both environmental and social value. This paper proposes an integrative analytical framework to embed social sustainability into circular business models, emphasising human capital, stakeholder engagement, and governance alignment as key levers for socially equitable circular transitions. The novelty of the paper lies in treating the ESG social pillar not as an additional reporting category but as an active transformation mechanism within circular business model change. Unlike CE–ESG approaches that primarily focus on environmental performance or aggregate social aspects into broader sustainability outcomes, this framework specifies how human capital development, stakeholder engagement, and governance alignment can jointly shape socially inclusive circular transitions. In this way, the paper contributes to CE and ESG management literature

by clarifying the social mechanisms through which circular strategies may generate measurable social value.

2 Theoretical Background

Although CE initiatives often affect employment and local communities (Ferrante et al., 2025), systematic measurement of social impacts remains scarce (Vanhuyse et al., 2021). Recent reviews argue for more inclusive CE frameworks that explicitly incorporate human and social dimensions alongside environmental targets (Mora-Contreras et al., 2023). ESG frameworks increasingly highlight social aspects, including labour standards, stakeholder relations, and community engagement (Martiny et al., 2024). While several CE–ESG conceptual models exist, most either marginalize the social dimension or aggregate it with environmental outcomes, leaving a gap for frameworks that operationalize social value creation systematically. This creates a theoretical limitation, because circular business models may generate environmental gains while simultaneously producing uneven social effects. For example, efficiency-oriented circular strategies can reduce material waste but may also reorganize work, shift risks to suppliers, or create new forms of insecure employment. Therefore, the social dimension should not be treated as an automatic consequence of circularity but as a distinct analytical and managerial concern.

However, empirical studies connecting ESG social performance to circular economy strategies are limited (Paea et al., 2023). The literature shows that firms can leverage ESG social metrics to enhance inclusivity and human capital development in circular transitions, but practical integration remains ad hoc and fragmented (Abbes, 2025). Stakeholder engagement is recognized as a critical mechanism for social value creation in CE initiatives (Oberholzer & Sachs, 2023). Employees, suppliers, and local communities influence the success of circular business models, yet research rarely examines how their involvement impacts social sustainability outcomes (Islam et al., 2025). Studies suggest that proactive engagement can mitigate negative social effects of CE transitions, such as workforce displacement or inequitable benefits distribution (Cerchione et al., 2025). Corporate governance structures can facilitate the integration of social sustainability objectives into circular business models (Al-Najjar et al., 2025). Governance mechanisms are critical for embedding ESG social considerations. In addition, workforce development, reskilling, and adaptive learning are increasingly recognized as prerequisites for successful CE transformations

(Eelager et al., 2025). Despite growing recognition of social sustainability, indicators for evaluating social impacts of CE are still underdeveloped. Current approaches often lack consistency, comparability, and operational feasibility. Consequently, there is a clear research gap in understanding how circular business model transformations can systematically integrate ESG social objectives, including human capital development, stakeholder engagement, and governance alignment.

3 Methodology

3.1 Conceptual Framework

Building on the literature, this paper proposes a conceptual framework that integrates the ESG social pillar into circular business model transformations. The framework positions social sustainability as a guiding principle shaping three key dimensions of CE initiatives: human capital development, stakeholder engagement, and corporate governance. Human capital development is conceptualized as a critical enabler of socially responsible circular transitions. Stakeholder engagement is treated as a mechanism through which social objectives are operationalized within circular value chains, particularly through the involvement of employees and local communities. Governance structures, such as board oversight, accountability mechanisms, and sustainability policies, are proposed to align circular strategies with ESG social objectives and ensure systematic integration. The framework also incorporates feedback loops, whereby social performance outcomes inform governance decisions and organizational learning. CE transformations are conceptualized as integrated sustainability processes capable of generating measurable social value alongside environmental benefits. The framework operationalizes social sustainability using indicators such as job quality, inclusion, and community well-being, which are linked to the feedback loops illustrated in Table 1.

3.2 Conceptual Research Approach and Model Development

This paper adopts a conceptual research approach aimed at theory building and model development. Rather than relying on empirical data, the framework is developed through a structured synthesis of literature on circular economy, ESG, social sustainability, stakeholder engagement, and corporate governance. A

conceptual approach is appropriate at this stage because the integration of the ESG social pillar into circular business model transformation remains fragmented and insufficiently theorized. Existing research identifies relevant social issues, such as employment effects, stakeholder participation, and governance accountability, but these elements are rarely connected into a coherent framework. The purpose of this paper is therefore not to test causal relationships empirically, but to clarify key constructs, specify their interrelationships, and provide a theoretically grounded basis for future empirical validation.

Key constructs and their interrelationships are identified and refined through iterative analysis and logical reasoning. The model maps the causal mechanisms linking circular business model transformations to social value creation, with governance and stakeholder engagement positioned as mediating mechanisms. Emphasis is placed on theoretical coherence and generalizability rather than empirical validation. The resulting framework provides a foundation for future empirical research, comparative analysis, and policy-oriented studies on socially inclusive circular economy transitions.

4 Analytical Elaboration Of The Conceptual Framework

Human capital development functions as a foundational mechanism in socially responsible circular transitions. Circular strategies often require new skills, adaptive learning, and changes in work organization. Without deliberate investment in reskilling, upskilling, and job quality, circular initiatives may unintentionally produce negative social outcomes, including workforce exclusion, job polarization, or the displacement of workers whose skills no longer match redesigned circular processes. Within the proposed framework, human capital development mitigates these risks by strengthening employability and enabling workers to participate in new circular activities such as repair, reuse, remanufacturing, and service-based models.

Stakeholder engagement complements human capital development by identifying which groups are affected by circular transformation and how benefits and burdens are distributed across the value chain. Employees, suppliers, and local communities may experience circular initiatives differently, therefore, their involvement helps reveal potential social risks before they become embedded in business model design. Governance alignment then provides the accountability structure through which

these concerns can be translated into measurable objectives, resource allocation, and performance monitoring.

Table 1: Conceptual framework illustrating the integration of the ESG social pillar into circular business model transformations

Key actors	Inputs	Actions	Outputs	Outcomes	Feedback
Employees HR/Management Training teams	Skills assessment tools, learning platforms, training budget	Reskilling programs, workshops, mentoring, adaptive work design	Employees acquire new skills, increased adaptability	Enhanced employability, job quality, workforce resilience	Employee performance and satisfaction inform further training cycles
Employees Local communities Suppliers NGOs	Engagement platforms, communication channels, participation incentives	Co-creation workshops, community consultations, supplier collaboration	Active stakeholder participation, feedback collection	Equity, inclusion, social legitimacy, co-created value	Feedback incorporated into design and strategy refinement
Board, Sustainability managers, Compliance officers	ESG reporting frameworks, governance charters, policy guidelines	Policy development, strategic decision-making, performance evaluation	Alignment of circular initiatives with social objectives	Consistent social performance, accountability, risk mitigation	Governance reviews adapt strategies based on social performance data
Sustainability teams Analysts HR	Social metrics, CE performance data, ESG indicators	Develop and track KPIs for job quality, inclusion, community well-being	Data on social performance	Evidence-based assessment of social value	KPI outcomes inform strategy adjustments and continuous improvement
All internal stakeholders	Knowledge management systems, lessons-learned repositories	Reflection sessions, best-practice documentation, workshops	Knowledge captured and shared	Continuous improvement of circular and social strategies	Lessons learned feed back into human capital development and stakeholder engagement
Local communities CSR teams	Community resources, partnerships, funding	Social projects aligned with circular initiatives	Community participation, local awareness	Enhanced well-being, social cohesion, community resilience	Community feedback informs future circular projects

The framework also acknowledges that circular business model transformations may involve trade-offs between environmental efficiency and social equity. For example, a Product-as-a-Service model may reduce material consumption and extend product lifecycles, but it can also reorganize employment relations, increase monitoring pressures, or create more precarious service-based jobs if social safeguards are absent. Similarly, automation-enabled circular operations may improve resource efficiency while reducing demand for certain occupational groups. These tensions demonstrate why social sustainability must be integrated into circular strategy from the design stage rather than assessed only after implementation. The framework suggests that higher levels of stakeholder engagement strengthen the social legitimacy and acceptance of circular business models. Furthermore, governance alignment plays a coordinating role by embedding social sustainability objectives into strategic decision-making. Governance mechanisms shape resource allocation, performance evaluation, and accountability structures, thereby influencing whether social considerations are systematically integrated or remain symbolic. Feedback loops within the framework indicate that social performance outcomes can inform governance adjustments and organizational learning over time.

These mechanisms illustrate how circular economy transformations can move beyond environmental efficiency toward broader social value creation. The analytical elaboration demonstrates that social outcomes are not automatic by-products of circularity but depend on deliberate organizational and governance choices. Table 1. presents the key mechanisms through which circular strategies generate social value. Human capital development enables workforce adaptation and skill acquisition, stakeholder engagement ensures inclusive participation across employees and local communities, and governance alignment embeds social objectives into strategic decision-making. Feedback loops illustrate the dynamic interactions between social performance outcomes and organizational learning, highlighting how circular economy transformations can produce both environmental and social value in an integrated manner.

5 Discussion

The proposed framework extends existing CE and ESG literature by positioning the social dimension as a transformation mechanism rather than as a secondary outcome of circularity. While many circular economy approaches primarily emphasize

environmental efficiency and resource optimization, the present framework highlights that circular business model change also restructures work, stakeholder relations, and governance responsibilities. This distinction is important because social value does not emerge automatically from circular practices, it depends on how organizations design, implement, and monitor circular strategies.

From a managerial perspective, the framework can be used as a diagnostic tool before and during circular business model transformation. For example, when a manufacturing company shifts from product sales to a repair- and service-based circular model, managers can assess whether affected employees receive reskilling opportunities, whether newly created service jobs provide adequate working conditions, and whether worker representatives or local communities are involved in redesigning roles and responsibilities. In this way, the framework supports the identification of social risks such as workforce displacement, job polarization, or exclusion from new circular value creation opportunities.

The framework also has implications for policymakers. Public support for circular economy initiatives should not focus exclusively on environmental performance indicators, but should also require evidence of social safeguards, inclusive training, stakeholder consultation, and community-level benefits. Linking circular economy policy with ESG social indicators can help ensure that the transition contributes to both environmental sustainability and social equity.

At the same time, the conceptual nature of the model represents a limitation. The framework is grounded in existing literature and theoretical reasoning, but it has not yet been empirically validated. Future research should test the framework across sectors and organizational contexts through case studies, surveys, or comparative analyses. Such research could examine whether the proposed indicators are measurable, comparable, and useful for managerial decision-making in practice.

6 Conclusions

This research has proposed a conceptual framework for integrating the ESG social pillar into circular business model transformations, highlighting human capital development, stakeholder engagement, and governance alignment as central mechanisms for generating social value. The framework offers both theoretical and

practical contributions. Theoretically, it bridges CE and ESG social literature, positioning social mechanisms as central rather than peripheral. Practically, it provides guidance for managers and policymakers on designing circular strategies that deliver measurable social benefits alongside environmental outcomes. Future research should empirically validate the framework across different sectors, regions, and organizational contexts. Comparative case studies, surveys, and simulation models could examine the effectiveness of human capital initiatives, stakeholder engagement, and governance practices in generating social value. Furthermore, operationalization of social sustainability indicators remains an open area, including developing robust, comparable, and feasible metrics for assessing social outcomes in circular business models (Csutora et al., 2022). Managers and policymakers can use the framework to design circular strategies that not only reduce environmental impact but also enhance social inclusion and workforce development. By foregrounding social value creation alongside environmental goals, this paper provides a foundation for future research and managerial practice, supporting more just and socially responsible circular economy transitions.

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TESTING THE WEAK-FORM EFFICIENT MARKET HYPOTHESIS IN SELECTED CENTRAL AND EASTERN EUROPEAN MARKETS

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This paper presents the results of testing the weak form of the Efficient Market Hypothesis (EMH) for the stock indices of Poland, Hungary, the Czech Republic, Slovakia, Slovenia, and Croatia using daily data for 2015–2024. The sample is split into two subperiods- 2015–2019 and 2020–2024 - with the cut at 1 January 2020 to capture the impact of the COVID-19 crisis on observed efficiency. The tests employed are the Lo–MacKinlay variance-ratio test, unit-root tests (ADF, Phillips–Perron), and serial-dependence tests (Ljung–Box Q and the runs test). For the full period, results are heterogeneous: the WIG (Poland) and BUX (Hungary) indices, on average, exhibit properties consistent with weak-form EMH, whereas the SAX (Slovakia) generally does not; the remaining indices display partial violations. After 2020, evidence in favour of weak-form efficiency declines noticeably for most indices, with outcomes varying in part by the test used.

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1 Introduction

The Efficient Market Hypothesis constitutes one of the fundamental concepts of modern financial theory, positing that the prices of financial instruments at any moment fully reflect all available information (Fama, 1970). In accordance with this definition, an efficient capital market enables the optimal allocation of resources to companies and thereby contributes to the effective functioning of the financial system and to a long-term economic growth. Fama (1970) distinguishes three forms of efficiency: weak, semi-strong, and strong. The weak form assumes that past prices do not contain information that would allow investors to systematically achieve above-average returns, whereas the semi-strong form encompasses all publicly available information, and the strong form also includes private or inside information.

The discussion of capital-market efficiency is of particular importance in transition economies which, after the collapse of central planning regimes (e.g., the Soviet Union, SFR Yugoslavia, Czechoslovakia), faced the challenge of constructing a modern financial system. The transition process included the establishment and strengthening of national capital markets as central mechanisms for the efficient allocation of financial resources. The initial period of transition was marked by low market capitalization, a limited number of financial instruments, a low degree of transparency, and a lack of investor confidence. Only after institutional reforms, accession to the European Union, and the opening of markets to foreign investors contributed to gradual stabilization, higher liquidity, and greater alignment with market standards (Claessens, Djankov, and Klingebiel, 2000).

Nevertheless, empirical studies (Gilmore and McManus, 2001; Hassan et al., 2006; Smith, 2012) indicate that, in their initial phases, the capital markets of transition economies mostly did not follow the weak form of efficiency, although over time improvements toward greater alignment with this concept were observed. This opens the research question of the further progress of selected capital markets in their capacity for efficient price formation.

The purpose of the study is to provide a comparative analysis of six selected capital markets in the Central and Eastern European (CEE) region over the recent period 2015–2024, which has not been previously examined in a unified framework for this

group of transition economies. It empirically evaluates whether these markets follow the weak form of the Efficient Market Hypothesis using multiple statistical tests and introduces a novel ranking of the six capital markets based on the consistency with which they satisfy the conditions of weak-form efficiency. Furthermore, the analysis incorporates a post-COVID-19 perspective by dividing the sample into two sub-periods (2015–2019 and 2020–2024), allowing for a structured comparison of the observed level of market efficiency before and after the pandemic, while also providing additional insight into market behaviour under systemic shocks.

The paper is structured as follows: Section 2 presents the literature review. Section 3 describes the data and outlines the methodological framework, including the selected statistical tests. Section 4 presents the empirical results, while Section 5 provides a summary of the key findings and concluding remarks.

2 Literature review

Research on these markets began to take shape in the early to mid-1990s, when post-transition markets were in an early stage of development. Among the first contributions for Poland, Gordon and Rittenberg (1995) analysed 1991–1994 and—based on the predictability of returns following trading halts during periods of elevated volatility—indicated violations of weak-form efficiency. Although they did not employ the full set of classical statistical tests, the signal was clear: in the early transition period, return predictability was present. For Hungary, Macskási and Molnár (1996) detected statistically significant serial correlation using the Ljung–Box test over 1991–1996, inconsistent with a random walk. In Czechia, an early study often cited is Vošvrda et al. (1998), which, using the variance-ratio test and autocorrelation tests for 1995–1997, found departures from random price movements; here too, early inefficiency aligns with the state of the market in the initial stages of institutional development.

The turn of the millennium brought broader, comparatively oriented analyses and greater methodological variety. Gilmore and McManus (2001) employed a combination of the Ljung–Box test, the variance-ratio test, and unit-root tests on daily data for Czechia, Poland, and Hungary. The results were mixed: in some instances, the tests failed to reject randomness, while elsewhere the diagnostics indicated predictable patterns—consistent with the view that efficiency can be time-

varying in transition markets, as year-by-year aggregations or rolling sub windows often reveal. Similarly, Smith and Ryoo (2003), using a multiple variance-ratio framework for Poland (1991–1998) and Hungary, found statistically significant departures from random price movements, consistent with observed inefficiency in the early stage of market development.

In the early 2000s, both methodological practices and observation frequencies broadened. Worthington and Higgs (2004) situated Czechia, Poland, and Hungary within a wider comparative framework of developed and emerging markets. For Czechia, the runs and unit-root tests indicated departures from a random walk, leading to an assessment of inefficiency over the period examined. Subsequent research, however, points to improvement in Czechia: focusing on volatility modelling and martingale properties, Hančlová and Rublíková (2006) find that the PX gradually approaches a random process. This shift from “clear” inefficiencies toward at least partial random-walk characteristics is a recurring theme across the region.

For Croatia, Heininen and Puttonen (2008) provide a different yet complementary perspective: instead of standard efficiency tests, they examine calendar anomalies (day-of-the-week, month-of-the-year, turn-of-the-month, and Halloween effects). In the period 1997–2000, an above-average turn-of-the-month return is observed, and the Halloween effect is statistically significant; taken together, this points to partial inefficiency, consistent with findings from related markets in early development phases. The Slovenian market was first studied at this time by Deželan (2000), who, using autocorrelation tests, detected serial dependence and thus rejected the weak form of the efficiency hypothesis for the Ljubljana Stock Exchange.

The years following the global financial crisis reduced the perception of these markets as weak-form efficient in many cases. For Croatia, Šonje, Alajbeg, and Bubas (2011), using a rolling autoregression for 1997–2010, show that CROBEX was efficient on approximately 80% of trading days (at the 5% level) prior to the crisis, compared with 98.9% for the S&P 500 up to 2007; after including post-2007 data, the share of efficient days falls to around 55%. This underscores the sensitivity of smaller, less liquid markets to systemic shocks. In a similar time window, Čelebić (2009), using daily data—autocorrelation, the runs test, and the variance-ratio test—likewise rejects the weak form of efficiency for Western Balkan markets (including

Croatian and Slovenian). Omay and Karadagli (2010), by contrast, find weak-form efficiency using unit-root tests; however, their use of monthly data and a longer observation period (2002–2010) partly smooths the impact of the financial crisis. Meanwhile, Dritsaki (2011) reports mixed results for 1997–2010—both in terms of which markets exhibit efficiency and which tests indicate it.

Smith (2012) tested 15 emerging European markets over 2000–2009 using rolling variants of the variance-ratio test (with focal windows 2002–2005 and 2006–2009) and computed the share of windows in which the random-walk hypothesis was not rejected. The rankings place Hungary 3rd, Poland 4th, and Czechia 6th, followed by Croatia (9th) and Slovakia (11th), while Slovenia ranks 14th out of 18 countries. A notable temporal cut is that, after 2006, efficiency deteriorates on most markets.

After 2010, the literature increasingly turns to more advanced – often nonlinear – unit-root tests intended to better capture potential structural breaks and asymmetries. Erdas (2019) examines eleven Central and Eastern European markets for 2010–2018 and generally confirms the presence of a unit root in return series – i.e., results consistent with weak-form market efficiency – for Czechia, Croatia, Hungary, and Slovakia, thereby broadly supporting the view that these markets are adaptive.

3 Data and methods

3.1 Data

The dataset comprises six equity indices: WIG (Poland), SBITOP (Slovenia), CROBEX (Croatia), PX (Czechia), SAX (Slovakia), and BUX (Hungary). The sample covers daily observations from the first trading day of 2015 to the last trading day of 2024, totalling approximately 2,486 trading days; the actual number of observations may differ slightly across indices due to local holidays and trading-calendar specifics. For each index, we use closing prices and compute logarithmic daily returns as $rt = \ln(P_t) - \ln(P_{t-1})$. The data were obtained from the Investing.com portal, and rows with missing or invalid values were removed without imputation.

To identify potential structural differences, we split the full sample into two subperiods: 2015–2019 and 2020–2024. All calculations and statistical tests (based on log-returns) were conducted in the Python programming language.

3.2 Methods

The empirical testing of the weak form of the Efficient Market Hypothesis rests on two complementary assumptions: (i) there is no serial dependence in returns, implying randomness of changes, and (ii) the logarithmic level of prices behaves as a unit-root process ($I(1)$), while its first differences – i.e., returns – are stationary. To test for serial dependence, tests of autocorrelation are used; in the present study the Ljung–Box test and the runs test will be included. The presence of a unit root will be examined using two complementary tests, namely the augmented Dickey–Fuller (ADF) unit-root test and the Phillips–Perron unit-root test. An intermediate bridge between the two groups of tests is provided by the Lo–MacKinlay test of the variance coefficient [variance-ratio test], which, on the basis of the properties of a random walk, derives a testable restriction concerning the linear growth of variance with the time lag. The joint use of these methods enables an expanded basis for inference, as they focus on different aspects of the same hypothesis: the correlation structure of returns, the randomness of the sequence of positive and negative returns, the temporal dynamics of variance, and the stationarity of the level of the price movement.

3.2.1. Ljung-Box Test

Ljung–Box is a test of joint autocorrelation designed to assess whether all autocorrelations up to a chosen lag h are simultaneously equal to zero. In the context of the weak form of the Efficient Market Hypothesis, its role is to examine whether the return series exhibits statistically significant serial (autocorrelative) structure that would permit forecasting future changes solely on the basis of past price movements. The method is standard in empirical analyses of market efficiency and, owing to its built-in small-sample correction, remains suitable for short and medium-sized samples—relevant for financial time series, where observations are often limited by data availability and regime shifts. The procedure is derived from the sum of squared sample autocorrelations up to h , with the finite-sample correction factor $n(n+2)/(n-k)$.

The Q statistic is given by:

$$Q = n(n+2) \sum_{k=1}^h \frac{\hat{\rho}k^2}{n-k}$$

The correction factor can equivalently be written as:

$$Q = n \sum_{k=1}^h w_k \hat{\rho}k^2, \quad w_k = \frac{n+2}{n-k}$$

The decision rule employs the χ^2 distribution with h degrees of freedom:

$$\text{Reject } H_0 \text{ if } Q > \chi_{h, 1-\alpha}^2, p\text{-value} = 1 - F_{\chi_h^2}(Q)$$

In practical implementation, a transparent choice of h is crucial: for small samples, a few lags suffice, whereas for longer series – especially when the aim is to detect weak and diffuse correlation patterns – the literature recommends a wider range (e.g., up to 20 or more), while recognizing the trade-off between test power and the increased risk of false rejections. Results are reported as pairs (Q, p) for each selected h (or for a set of h values), together with an explicit decision at a pre-specified significance level α and a statement on robustness across similar h -specifications and subsamples. The test's role within the suite of complementary procedures is diagnostic: it does not measure the magnitude of departures from a random walk in terms of the dynamic structure of variance or the stationarity of levels, but rather the aggregate presence of linear dependencies of the first (and higher) orders; consequently, its findings should be interpreted in combination with other tests.

3.2.2 Runs Test

Runs test is a nonparametric test of the randomness of the direction of changes in a time series. A run is defined as the maximal sequence of consecutive observations with the same sign (e.g. ++ -- + contains the runs ++, --, and +). In the methodological exposition, we first determine the numbers of positive and negative changes, N^+ and N^- , and the total number of observations $N = N^+ + N^-$. The

expected number of runs under the null hypothesis of a random arrangement of signs is given by

$$m = 1 + \frac{2 N^+ N^-}{N}$$

The result of the runs test is expressed by the value of the Z-statistic, which is computed according to the following equation:

$$Z = \frac{R - m}{\sigma_m}$$

where the standard deviation of the expected number of runs is computed using the equation:

$$\sigma_m = \sqrt{\frac{2 N^+ N^- (2 N^+ N^- - N)}{N^2 (N - 1)}}$$

Results are interpreted based on the absolute value of the Z-statistic: values exceeding 1.96 imply rejection of the null of randomness at the 5% significance level, while values exceeding 2.58 imply rejection at the 1% level. Rejection of the null indicates the presence of non-random patterns in return changes—i.e., serial dependence—which constitutes a departure from the assumptions of weak-form market efficiency.

3.2.3 Variance-Ratio Test

The Lo–MacKinlay variance-ratio test is a statistical procedure for testing the weak form of market efficiency. It rests on the premise that, under a random walk, the variance of cumulative (k-period) returns is linearly proportional to the length of the observation interval.

The basic variance-ratio can be written as:

$$VR(q) = \frac{Var(R_t(q))}{q Var(R_t(1))}$$

Under a random walk, the variance ratio, $VR(q)$, should be close to 1. Deviations from this value indicate two cases: if $VR(q) < 1$, this points to mean reversion (negative autocorrelation), whereas $VR(q) > 1$ indicates momentum (positive autocorrelation).

The computation of the variance-ratio test statistic depends on assumptions about the distribution of returns. Lo and MacKinlay (1988) define two versions of the statistic: $M1(q)$, which assumes independent and identically distributed (i.i.d.) returns (the RW1 framework) with the corresponding asymptotic variance $\phi(q)$; and $M2(q)$, which is robust to heteroskedasticity (the RW3 framework).

The $M1$ statistic can be written as:

$$M_1(q) = \frac{VR(q) - 1}{\sqrt{\phi(q)}}$$

where the asymptotic variance can be computed as:

$$\phi(q) = \frac{2(2q-1)(q-1)}{3qT}$$

In the case where heteroskedasticity of return distributions is assumed—which is characteristic of financial time series—we use the $M2(q)$ statistic, defined as:

$$M_2(q) = \frac{VR(q)-1}{\sqrt{\phi^*(q)}}, \text{ where } \phi^*(q) = \sum_{j=1}^{q-1} \left[\frac{2(q-j)}{q} \right]^2 \delta(j)$$

$$\delta(j) = \sum_{t=j+1}^T (x_t - \bar{x})^2 (x_{t-j} - \bar{x})^2 \left[\sum_{t=1}^T (x_t - \bar{x})^2 \right]^{-2}$$

In the equations, x_t denotes the one-period logarithmic return, $\bar{x}$ the arithmetic mean of the time series, q the selected lag, and T the number of observations in the sample.

The statistics $M1(q)$ and $M2(q)$ are Z-statistics that are compared with the critical values of the standard normal distribution. If the absolute value of the Z-statistic exceeds the critical threshold (e.g., ± 1.96 for the 5% significance level), we reject the

null hypothesis of a random walk. This means that the return series exhibits a statistically significant autocorrelation structure, which is contrary to the weak form of market efficiency.

Since financial time series often display heteroskedasticity, the empirical part of the study will employ the more robust $M2(q)$ statistic.

3.2.4 Unit Root Tests

Unit root tests are statistical tools for assessing the stationarity of time series. In the context of the weak form of the EMH, it is crucial to determine whether the levels of log prices follow a random walk, implying non-stationarity and the presence of a unit root. If the series is stationary, this points to mean-reverting mechanisms, which allow a degree of predictability and run counter to the weak form of the EMH.

Two complementary tests are employed: the Augmented Dickey–Fuller (ADF) test and the Phillips–Perron (PP) test. Both test the null hypothesis $H0$: the time series contains a unit root (is non-stationary), against the alternative $H1$: the time series is stationary.

The Augmented Dickey–Fuller (ADF) test extends the basic DF test by including lags of the first differences of the dependent variable to explicitly capture autocorrelation in the errors. The test is based on estimating the following regression equation:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^p \delta_i \Delta y_{t-i} + \varepsilon_t$$

Where Δy_t is the first difference; α is a constant (drift); βt represents a deterministic linear trend; γy_{t-1} is the key term for the unit-root test $\sum_{i=1}^p \delta_i \Delta y_{t-i}$; includes lagged differences to capture short-run dynamics and remove serial correlation; and ε_t is a random disturbance (white noise).

The test statistic is compared with the critical values of the Dickey–Fuller distribution. If the statistic falls below the negative critical value (e.g., -2.86 at the 5% significance level), H_0 is rejected and the series is concluded to be stationary.

The Phillips–Perron (PP) test takes a different approach. Instead of including lags of first differences of the dependent variable, it applies a nonparametric correction to adjust the standard errors of the test statistic so as to account for heteroskedasticity and higher-order autocorrelation. It is based on the basic DF regression without additional dynamic terms:

$$\Delta y_t = \alpha + \beta t + \phi y_{t-1} + \varepsilon_t$$

The principal advantage of the PP test is its robustness to a wide range of heteroskedasticity and autocorrelation patterns without requiring the specification of the lag order p . The test statistic is computed as a modified version of the DF statistic with a correction factor for the long-run variance $\hat{\sigma}^2$.

It can be written as follows:

$$Z_t = \frac{\hat{\gamma}}{\text{SE}(\hat{\gamma})} - \frac{1}{2} \left(\frac{\hat{\lambda}^2 - \hat{\sigma}_u^2}{\hat{\sigma}^2} \right) \cdot \frac{T \cdot \text{SE}(\hat{\gamma})}{\hat{\sigma}_u}$$

where $\hat{\lambda}^2$ is the estimate of the long-run variance of the residuals, while $\hat{\sigma}_u^2$ is the estimate of the short-run (contemporaneous) variance of the residuals. The decision rules are identical to those for the ADF test: reject H_0 (unit root) if the PP test statistic Z_t is more negative than the corresponding Dickey–Fuller critical value for the chosen deterministic specification (no constant / with constant / with trend) at the selected significance level.

4 Results and discussion

4.1 Ljung–Box Test

The Ljung–Box autocorrelation test results are reported in Appendix A (full period: Table A1; subperiods: Table A2). The full-period analysis covers ten years between 2015 and 2024 ($n=2,486$ observations). Testing the null hypothesis H_0 :

$\rho_1=\rho_2=\dots=\rho_m=0$ (no serial dependence up to the chosen lag) shows that H_0 is rejected for all indices except Poland's WIG, which alone does not exhibit departures from a random walk. In terms of rejection strength, Croatia's CROBEX stands out: its Q -statistics substantially exceed those of the other indices at all inspected lags, indicating a stronger joint departure from H_0 either due to a few larger autocorrelation coefficients or to numerous smaller ones that cumulate.

We split the sample into two subperiods with a breakpoint in 2020 to capture potential structural changes following the COVID-19 shock. Before 2020, in addition to WIG, we do not detect statistically significant serial dependence for SBITOP or BUX (i.e., H_0 is not rejected), whereas the PX results do not materially differ from the full-period findings and are not consistent across lags. After 2020, however, Hungary's BUX and Slovenia's SBITOP begin to exhibit statistically significant serial dependence, suggesting a deterioration in weak-form efficiency on these markets in the post-pandemic period. For Croatia's CROBEX and Slovakia's SAX, serial dependence is present across all periods considered.

4.2 Runs Test

The runs-test results are provided in Appendix B—Table B1 for the full period and Table B2 for the subperiods. Over the full sample there are approximately 2,486 observations; for Slovakia's SAX, the number is lower—about 1,634—because days with no change in the index price are excluded from the runs test. Approximately 1,200 runs are observed.

For four indices, p -values exceed 0.05; thus, the null hypothesis H_0 (runs are random) is not rejected, meaning the sign sequence of returns is consistent with a random walk and with the weak form of efficiency over the tested horizon. By contrast, for PX and SAX the p -values fall below 0.05, so H_0 is rejected, implying that the sign sequence is not random. The direction of the departure accords with the sign of the Z -statistic: too many runs ($Z > 0$) indicate mean reversion, whereas too few runs ($Z < 0$) indicate momentum (trend persistence). In our case, this suggests mean reversion for PX and momentum for SAX. For the remaining indices, any tendencies (e.g., a mild tilt toward mean reversion) are not statistically significant ($p > 0.05$).

In the subperiod split, the key change concerns PX: in 2015–2019, H_0 is rejected ($\alpha = 0.05$), indicating a non-random sign sequence. For the other indices, results are broadly similar to the baseline in terms of strength (rejections vs. non-rejections of H_0) and the direction of departures, with the exception of SBITOP, which shows slight momentum (too few runs; $Z < 0$). In 2020–2024, H_0 is not rejected only for WIG, CROBEX, and BUX ($p > 0.05$; results for WIG and CROBEX are strongly consistent with H_0). PX is at the threshold of statistical significance ($p \approx 0.05$), while SAX and SBITOP reject H_0 . Based on the Z-values, the direction of departures is clear: SAX exhibits strong momentum (too few runs; $Z < 0$), whereas SBITOP exhibits mean reversion (too many runs; $Z > 0$).

4.3 Variance-Ratio Test

The full-period results are presented in Appendix C, Table C1. The subperiod results are reported in Appendix C, Table C2. For the full sample, the Lo–MacKinlay variance-ratio test indicates that the null hypothesis H_0 (prices follow a random walk) is not rejected only for two indices—Poland’s WIG and Hungary’s BUX—and this holds consistently across all inspected aggregation intervals q . For PX and SBITOP, H_0 is rejected at all aggregation intervals except one, whereas for CROBEX and SAX it is rejected at all intervals. In terms of direction, nearly all indices (except SAX) exhibit momentum for most q (i.e., $VR(q) > 1$), while SAX points to mean reversion (i.e., $VR(q) < 1$).

In 2015–2019, only SAX rejects H_0 ; CROBEX shows mixed outcomes depending on the chosen aggregation interval q . For all other indices H_0 is not rejected, with the caveat that WIG displays a departure at the first interval. By direction, most indices in this subperiod indicate mean reversion, whereas CROBEX exhibits more marked momentum.

After 2020, the findings align more closely with the full-period results: H_0 is not rejected only for BUX and WIG. The direction of departures mostly indicates momentum, with SAX again standing out for marked mean reversion. Results are consistent across aggregation intervals, with a minor exception for WIG, where estimates at some intervals lie very close to the rejection thresholds

4.4 Unit Root Tests

The unit-root test results are provided in Appendix D–Table D1 for the 2015–2024 period and Table D2 for the subperiods. Over the full sample, for all indices the ADF and Phillips–Perron (PP) tests do not reject the null hypothesis H_0 (presence of a unit root, i.e., $I(1)$); for CROBEX, the heteroskedasticity-robust PP result is at the threshold of statistical significance (p-value around 0.05), yet H_0 still cannot be reliably rejected. Because we test log prices, such outcomes—i.e., non-rejection of H_0 and thus $I(1)$ —are compatible with the weak form of the EMH (the random-walk property of prices).

In the subperiod analysis, there are no material departures. Notably, for CROBEX the subperiod results provide clearer support for H_0 (hence $I(1)$), in contrast to the borderline outcome in the full sample. Differences between the two tests (ADF vs. PP) appear only as minor variations in p-values, while across subperiods we observe some fluctuation in the “strength” of (non-)rejection for specific indices (especially BUX and PX). These do not alter the central conclusion: in all cases, the unit-root null H_0 is not rejected.

4.5 Reasons for Divergence in Empirical Tests Results of Weak-Form Market Efficiency

Differences in assessing the ability of individual indices to follow the weak form of the Efficient Market Hypothesis arise primarily because the statistical tests used measure different aspects of efficiency. As already highlighted in the methodology section, testing the weak form of the EMH through the random walk model implies two verifiable properties of financial time series: (i) the absence of serial dependence in returns and (ii) the non-stationarity of price series (i.e., the presence of a unit root). Non-stationarity implies that the statistical properties of a time series, such as the mean, variance, and covariance, change over time. However, satisfying this condition represents only a necessary, but not sufficient, condition for the validity of the weak form of the EMH. As emphasized by Rahman and Saadi (2008), a time series can be non-stationary (in prices) or stationary (in returns) while still being predictable, thereby violating the core requirement of the Efficient Market Hypothesis. The

reliability of unit root tests may be further limited by the presence of structural breaks.

Additional discrepancies in results also arise from tests that examine the absence of predictability or independence of returns. The random walk model, as a framework for testing the weak form of the EMH, was formalized into three hierarchical forms by Campbell, Lo, and MacKinlay (1997). The first-order random walk model (RW1) assumes independent and identically distributed (i.i.d.) returns with constant variance (homoskedasticity). The second-order model (RW2) relaxes the identical distribution assumption by allowing returns to be independent but not identically distributed – permitting unconditional heteroskedasticity – while still requiring full statistical independence between observations. The third-order model (RW3) further relaxes the independence assumption by allowing for conditionally dependent increments, requiring only that returns remain serially uncorrelated rather than fully independent. This formulation accommodates time series in which dependence exists in higher-order moments, such as the conditional variance, even in the absence of linear autocorrelation in returns.

The remaining statistical tests used in this study can be classified according to the aspect of dependence or randomness they detect. The variance ratio test directly examines consistency with the random walk model, and under its heteroskedasticity-robust specification (Lo and MacKinlay, 1988), is robust to the conditional heteroskedasticity characteristic of RW3. Consequently, under less restrictive assumptions, it more often confirms weak-form market efficiency than tests requiring full independence. In contrast, the Ljung–Box test examines only linear uncorrelatedness of returns, which is a necessary but not sufficient condition for a random walk, as it does not capture nonlinear dependencies nor ensure full independence of returns. Moreover, the Ljung–Box test often leads to more frequent rejections of the null hypothesis because it requires the absence of linear autocorrelation across all observed lags; even a single statistically significant autocorrelation coefficient is sufficient to reject the null. Since financial time series often exhibit weak but persistent short-term dependencies and heteroskedasticity, this condition is rarely fully satisfied in practice. The runs test, on the other hand, evaluates the randomness of the sequence of returns and is therefore predominantly associated with testing the stricter form of the random walk (RW1), which assumes complete independence of returns. Its rejection thus indicates the presence of

nonlinear patterns in the series, even in the absence of linear autocorrelation (Roldán-Casas and García-Moreno García, 2022).

5 Conclusions

The summary of the tests performed is reported in Appendix E (Table E1). The results point to differences in compliance with the conditions for weak-form efficiency across the markets examined. WIG and BUX stand out as relatively weak-form efficient, meeting the conditions in almost all tests, with a slight edge for WIG (in terms of the strength of rejections in the statistical procedures employed). PX, SBITOP, and—conditionally—CROBEX can be classified as partially weak-form efficient: although the number of null-hypothesis rejections for CROBEX is comparable to PX and SBITOP, the departures in the tests where conditions were not met are more pronounced and, in their characteristics, closer to SAX, which we classify as weak-form inefficient. In a direct SBITOP–PX comparison we give preference to PX, since for it we observe stronger rejections of the null hypothesis in the selected tests. final ranking of indices is presented in Appendix E (Table E2).

We also note divergences in results across statistical procedures, as different statistical tests are designed to examine different assumptions or conditions of the random walk model, which in turn determine the acceptance or rejection of the weak-form Efficient Market Hypothesis. Unit root tests most often fail to reject the null hypothesis, which in this case implies the presence of a unit root in log price series, i.e. non-stationarity. This represents a necessary, but not sufficient, condition for the validity of the weak-form EMH. Following these, the variance ratio test examines the broadest form of the random walk model (RW3), while the runs test is consistent with the assumptions of RW1. The Ljung–Box test, similarly to unit root tests, assesses only the condition of no autocorrelation; however, due to the requirement that the null hypothesis must hold across all lags, it is frequently rejected.

In the subperiod split, a structural shift after 2020 is evident: rejections of the null hypothesis are markedly rarer after the COVID-19 period than before it. Özkan (2021) cites as possible reasons the strengthened role of monetary and fiscal policy, the increased participation of retail investors, and departures of macroeconomic indicators from typical levels, which complicate their interpretation; additional

macroeconomic shocks and geopolitical events may further have reduced market efficiency. The variability of observed efficiency is also consistent with Lo's (2004) Adaptive Markets Hypothesis, according to which markets temporarily depart from weak-form efficiency during periods of major shocks and heightened uncertainty.

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Appendix a

Table A1. Ljung-Box test results for the full period (2015-2024).

Indices	Lag5 (Q value, p-value)	Lag10 (Q value, p-value)	Lag20 (Q value, p-value)
Period	2015-2024	2015-2024	2015-2024
BUX	26,92 (0,0001)	40,94 (0,0000)	63,80 (0,0000)
CROBEX	129,84 (0,0000)	157,24 (0,0000)	179,88 (0,0000)
PX	24,09 (0,0002)	33,06 (0,0003)	61,12 (0,0000)
SAX	33,07 (0,0000)	45,98 (0,0000)	52,14 (0,0001)
SBITOP	41,99 (0,0000)	55,22 (0,0000)	69,78 (0,0000)
WIG	7,43 (0,1906)	12,64 (0,2443)	20,54 (0,4241)

Source: Author's calculations.

Table A2. Ljung-Box test results for subperiods.

Indices	Lag 5 (Q value, p-value)		Lag 10 (Q value, p-value)		Lag 20 (Q value, p-value)	
	2015–2019	2020–2024	2015–2019	2020–2024	2015–2019	2020–2024
Period						
BUX	8,12 (0,1496)	27,68 (0,0000)	16,42 (0,0881)	40,55 (0,0000)	25,82 (0,1717)	63,76 (0,0000)
CROBEX	35,53 (0,0000)	122,23 (0,0000)	69,01 (0,0000)	148,20 (0,0000)	88,75 (0,0000)	174,60 (0,0000)
PX	12,64 (0,0269)	27,28 (0,0001)	15,09 (0,1287)	41,83 (0,0000)	27,11 (0,1321)	75,43 (0,0000)
SAX	21,59 (0,0006)	16,76 (0,0050)	28,71 (0,0014)	26,35 (0,0033)	38,26 (0,0082)	35,51 (0,0175)
SBITOP	6,07 (0,2991)	41,52 (0,0000)	9,52 (0,4835)	53,71 (0,0000)	23,71 (0,2553)	69,23 (0,0000)
WIG	13,96 (0,0158)	7,11 (0,2119)	16,08 (0,0973)	13,95 (0,1751)	24,74 (0,2114)	25,07 (0,1987)

Source: Author's calculations.

Appendix b

Table B1. Runs test results for full period (2015-2024).

Runs test (2015-2024)					
Indices	Observations	Observed runs	Expected runs	Z-statistics	p-value
BUX	2485	1204	1234	-1,20	0,2301
CROBEX	2483	1234	1236	-0,08	0,9341
PX	2485	1182	1236	-2,18	0,0292
SAX	1634	958	816	7,07	0,0000
SBITOP	2486	1215	1240	-1,01	0,3132
WIG	2486	1230	1242	-0,50	0,6172

Source: Author's calculations.

Table B2. Runs test results for subperiods.

Runs test for subperiods										
Indices	Observations		Observed runs		Expected runs		Z-statistics		p-value	
Period	2015 - 2019	2020-2024	2015-2019	2020-2024	2015-2019	2020-2024	2015-2019	2020-2024	2015-2019	2020-2024
BUX	1241	1244	612	593	616	619	-0,23	-1,47	0,8194	0,1428
CROBEX	1241	1242	614	620	621	615	-0,38	0,31	0,7009	0,7543
PX	1241	1244	600	583	619	617	-1,10	-1,96	0,2700	0,0501
SAX	965	669	539	419	480	335	3,86	6,46	0,0001	0,0000
SBITOP	1242	1244	641	575	622	616	1,08	-2,36	0,2797	0,0181
WIG	1242	1244	600	630	621	622	-1,22	0,46	0,2223	0,6458

Source: Author's calculations.

Appendix c

Table C1: Variance-ratio test results for full period (2015-2024).

Indices	Lag (q)	VR	Z-statistics	p-value
BUX	2	1,01	0,73	0,4641
	4	1,01	0,30	0,7664
	8	1,02	0,39	0,6999
	16	1,05	0,52	0,6056
	32	1,09	0,70	0,4848
CROBEX	2	0,97	-1,38	0,1668
	4	1,12	3,29	0,0010
	8	1,37	6,32	0,0000
	16	1,65	7,31	0,0000
	32	1,69	5,42	0,0000
PX	2	1,04	1,91	0,0562
	4	1,15	4,05	0,0001
	8	1,22	3,77	0,0002
	16	1,28	3,18	0,0014
	32	1,21	1,61	0,1079
SAX	2	0,89	-5,39	0,0000
	4	0,79	-5,49	0,0000
	8	0,73	-4,53	0,0000
	16	0,62	-4,26	0,0000
	32	0,48	-4,04	0,0000
SBITOP	2	1,04	1,83	0,0670
	4	1,16	4,15	0,0000
	8	1,30	5,05	0,0000
	16	1,51	5,77	0,0000
	32	1,56	4,35	0,0000
WIG	2	1,02	0,87	0,3820
	4	1,04	1,02	0,3067
	8	1,07	1,17	0,2427
	16	1,15	1,67	0,0959
	32	1,13	0,98	0,3279

Source: Author's calculations.

Table C2: Variance ratio test results for subperiods.

Indices	Lag (q)	VR	Z-statistics	p-value	VR	Z-statistics	p-value
Period		2015-2019			2020-2024		
BUX	2	1,01	0,29	0,7704	1,02	0,64	0,5232
	4	0,97	-0,61	0,5439	1,03	0,61	0,5408
	8	0,85	-1,74	0,0810	1,11	1,29	0,1975
	16	0,81	-1,51	0,1306	1,16	1,31	0,1904
	32	0,82	-0,97	0,3330	1,23	1,27	0,2056
CROBEX	2	1,07	2,51	0,0120	0,93	-2,43	0,0149
	4	1,03	0,58	0,5620	1,16	3,05	0,0023
	8	1,12	1,43	0,1539	1,48	5,76	0,0000
	16	1,30	2,44	0,0147	1,79	6,34	0,0000
	32	1,56	3,09	0,0020	1,76	4,21	0,0000
PX	2	1,01	0,23	0,8218	1,06	1,97	0,0489
	4	1,02	0,31	0,7577	1,23	4,26	0,0000
	8	0,95	-0,54	0,5861	1,37	4,42	0,0000
	16	0,86	-1,10	0,2715	1,51	4,10	0,0000
	32	0,71	-1,62	0,1049	1,48	2,68	0,0073
SAX	2	0,88	-4,09	0,0000	0,90	-3,45	0,0006
	4	0,77	-4,35	0,0000	0,83	-3,30	0,0010
	8	0,66	-4,06	0,0001	0,82	-2,13	0,0332
	16	0,56	-3,49	0,0005	0,69	-2,46	0,0138
	32	0,40	-3,34	0,0009	0,57	-2,37	0,0179
SBITOP	2	0,98	-0,57	0,5675	1,06	2,12	0,0336
	4	0,98	-0,31	0,7551	1,23	4,32	0,0000
	8	0,98	-0,21	0,8335	1,43	5,13	0,0000
	16	1,06	0,46	0,6473	1,70	5,62	0,0000
	32	1,18	0,99	0,3231	1,71	3,91	0,0001
WIG	2	1,07	2,49	0,0128	1,00	-0,11	0,9118
	4	1,05	0,95	0,3431	1,03	0,66	0,5112
	8	0,98	-0,27	0,7882	1,11	1,28	0,2018
	16	0,89	-0,89	0,3726	1,25	2,04	0,0417
	32	0,93	-0,37	0,7113	1,22	1,21	0,2281

Source: Author's calculations.

Appendix d

Table D1: Unit root test results for full period (2015-2024).

Unit root test				
2015-2024				
Indices	ADF Statistics	ADF p-value	PP Statistics	PP p-value
BUX	-0,34	0,9200	-0,42	0,9069
CROBEX	-2,92	0,0428	-2,86	0,0496
PX	-2,19	0,2095	-2,33	0,1619
SAX	0,11	0,9664	0,11	0,9668
SBITOP	-2,26	0,1850	-2,20	0,2074
WIG	-2,25	0,1872	-2,36	0,1533

Source: Author's calculations.

Table D2: Unit root test results for subperiods.

Unit root test								
Indices	ADF Statistics	ADF p-value	ADF Statistics	ADF p-value	PP Statistics	PP p-value	PP-statistics	PP p-value
Period	2015-2019		2020-2024		2015-2019		2020-2024	
BUX	0,85	0,9924	-2,15	0,2251	1,12	0,9954	-2,21	0,2044
CROBEX	-2,05	0,2659	-2,16	0,2217	-2,06	0,2599	-2,09	0,2493
PX	-1,76	0,4000	-1,63	0,4700	-1,77	0,3973	-1,77	0,3978
SAX	0,19	0,9715	-2,02	0,2800	0,64	0,9886	-2,00	0,2871
SBITOP	-2,03	0,2745	-1,72	0,4226	-2,07	0,2561	-1,69	0,4348
WIG	-1,39	0,5887	-1,69	0,4367	-1,33	0,6150	-1,81	0,3736

Source: Author's calculations.

Appendix e

Table E1: Tests results summary.

(2015-2024)	LJUNG-BOX TEST	RUNS TEST	VR	UNIT ROOT TEST
BUX	-	+	+	+
CROBEX	-	+	-	-/+
PX	-	-	-/+	+
SAX	-	-	-	+
SBITOP	-	+	-	+
WIG	+	+	+	+
2015-2019				
BUX	+	+	+	+
CROBEX	-	+	+	+
PX	-/+	+	+	+
SAX	-	-	-	+
SBITOP	+	+	+	+
WIG	-/+	+	+	+
2020-2024				
BUX	-	+	+	+
CROBEX	-	+	-	+
PX	-	-/+	-	+
SAX	-	-	-	+
SBITOP	-	-	-	+
WIG	+	+	+	+

Source: Author's calculations.

Table E2: Final rankings of selected indices.

Indices	Number of rejected H_0
WIG	11,5
BUX	10
PX	6,5
SBITOP	7
CROBEX	6,5
SAX	3

Source: Author's calculations.

FROM TRADITIONAL TO AI-AUGMENTED PROJECT MANAGEMENT: RETHINKING GOVERNANCE AND MANAGERIAL ROLES

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The rapid diffusion of artificial intelligence (AI) is fundamentally reshaping managerial work and governance structures in project-based organizations. As projects increasingly function as primary vehicles for digital and sustainability-driven transformation, traditional project management models - grounded in linear planning, human-centered decision-making, and static governance arrangements - face growing limitations in coping with heightened complexity, uncertainty, and interdependence. While existing research has largely focused on AI as a technical tool for improving forecasting, monitoring, and operational efficiency, its broader implications for project governance and managerial roles remain underexplored. This conceptual paper examines the transition from traditional to AI-augmented project management through a systematic synthesis of literature from project management, organizational governance, decision-making, and artificial intelligence. The analysis highlights how AI reshapes key phases of the project lifecycle, alters decision-making logics, and reconfigures the role of the project manager from a primary decision-maker toward a sense maker, orchestrator, and steward of AI-supported decisions. Building on this synthesis, the paper introduces the concept of AI-augmented project governance as a theoretical framework that addresses emerging challenges related to accountability, transparency, and alignment with sustainability and ESG principles. The paper concludes by outlining implications for project management theory and proposing directions for future empirical research.

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1 Introduction

Organizations are currently navigating a dual transformation: digital acceleration and sustainability reorientation. On the one hand, rapid advances in artificial intelligence (AI), machine learning, and data-driven decision systems are reshaping how organizations generate knowledge, allocate resources, and govern performance. On the other hand, increasing pressure to align corporate activities with environmental, social, and governance (ESG) principles is redefining the normative foundations of managerial responsibility. AI is increasingly positioned as a driver of business model transformation and sustainable value creation, particularly in relation to the Sustainable Development Goals (Di Vaio et al., 2020).

Projects constitute the primary organizational mechanism through which digital and sustainability ambitions are operationalized. Whether implementing digital infrastructures, restructuring organizational processes, or delivering sustainability initiatives, projects translate strategic intent into coordinated action. Yet project management, as a field, has historically evolved from early technical scheduling techniques toward institutionalized management models (Garel, 2013). Even as methodologies diversified - from predictive (waterfall) to agile and hybrid forms - the underlying governance logic largely preserved a human-centered decision architecture in which managers remain the focal point of responsibility and coordination.

This architecture is increasingly strained. Contemporary projects operate under heightened complexity, uncertainty, and ambiguity, conditions that challenge traditional assumptions of predictability. Governance research further emphasizes that projects are embedded in broader strategic and stakeholder contexts; project governance must therefore ensure alignment between projects and organizational strategy (Costantino et al., 2015; Hazır, 2014).

Simultaneously, artificial intelligence has emerged as one of the most consequential technologies in management discourse. As Einola and Khoreva (2023) observe, “Artificial intelligence (AI) is a modern-day buzzword, a topic of ongoing debate... presently transforming our work lives”. AI is frequently conceptualized as capable of “learning, interacting, and problem solving” (Einola & Khoreva, 2023), thereby

extending beyond automation into cognitive domains traditionally reserved for managerial judgment.

In project management specifically, AI is increasingly associated with predictive analytics, estimation accuracy, resource optimization, and real-time monitoring. For example, research on AI-assisted project management highlights how AI can “automate routine and repetitive tasks” and improve estimation and risk prediction (Zadeh et al., 2024). While such applications promise improved analytical performance, they also introduce shifts in epistemic authority: algorithmic systems begin to influence which risks are visible, which alternatives are prioritized, and which outcomes are considered optimal.

Importantly, AI adoption in business contexts is not purely technical. Cubric (2020) emphasizes that while drivers of AI adoption are “mainly economic,” barriers include “technical aspects... as well as social considerations such as... increased dependence on non-humans, job security, lack of knowledge, safety, trust”. These concerns directly intersect with project environments, where responsibility, transparency, and stakeholder trust are central governance principles.

Despite the growing body of research on AI-assisted forecasting, monitoring, and decision-support tools (Pal et al., 2023; Bento et al., 2022), the broader implications for project governance and managerial roles remain theoretically underdeveloped. If AI increasingly participates in core project functions - planning, monitoring, prioritization - then the foundational assumptions of project management as a human-centered discipline require reconsideration. The critical question is no longer whether AI improves project performance, but how its integration reconfigures decision-making logics, accountability structures, and the role of the project manager.

This paper addresses this theoretical gap by conceptually examining the transition from traditional to AI-augmented project management. Drawing on interdisciplinary literature from project management, governance theory, artificial intelligence, and organizational research, the study develops a framework for understanding how AI reshapes the project lifecycle, redistributes managerial authority, and imposes new forms of governance. In doing so, the paper introduces the notion of *AI-augmented*

project governance to capture the emerging configuration in which algorithmic systems and human actors jointly influence project outcomes.

The remainder of the paper is structured as follows. The next section outlines the key characteristics and governance logics of traditional project management models - predictive, agile, and hybrid - establishing the analytical baseline for the study. This is followed by a conceptual overview of artificial intelligence in management, focusing on decision support, automation, and accountability. The central section examines the transition to AI-augmented project management, analyzing how AI reshapes project lifecycle processes and managerial roles, and introduces the concept of *AI-augmented project governance*. The discussion evaluates the opportunities and challenges of AI integration, particularly regarding ethical responsibility and ESG alignment, and the conclusion summarizes the main conceptual contributions and outlines directions for future research.

2 Conceptual Approach and Scope of the Study

This paper adopts a conceptual and interdisciplinary approach to examining the transition from traditional to AI-augmented project management. Rather than empirically testing hypotheses, the study synthesizes insights from project management literature, governance theory, organizational management research, and emerging scholarship on artificial intelligence in business contexts. The objective is not to evaluate specific AI tools or technologies, but to develop a theoretically grounded understanding of how AI integration reshapes governance structures, managerial authority, and decision-making processes in project environments.

The paper is positioned as a conceptual synthesis that integrates and critically interprets existing literature across multiple domains. Particular emphasis is placed on project governance, managerial roles, accountability structures, AI-enabled decision support, and ESG-related governance challenges. By combining these streams of research, the study aims to develop a broader theoretical lens for understanding AI not merely as an operational enhancement, but as a governance-level transformation affecting the architecture of project management itself.

Given the conceptual nature of the paper, the proposed framework of AI-augmented project governance should be understood as an analytical and theoretical contribution intended to support future empirical research, comparative studies, and governance model development.

3 Traditional project management models and governance logics

Project management has evolved through distinct methodological paradigms, yet across these variations, a relatively stable governance logic has persisted. From early predictive models to agile and hybrid approaches, project management has remained anchored in structured decision-making architectures, predefined accountability structures, and human-centered authority.

The predictive or waterfall model represents the classical paradigm of project management. Rooted in engineering logic and formal planning traditions, it assumes that project objectives can be clearly defined *ex ante* and that uncertainty can be mitigated through detailed planning, sequencing, and control mechanisms (Garel, 2013). Decision-making authority in this model is hierarchical, with the project manager serving as the central coordinating agent responsible for planning, monitoring, and corrective intervention. Governance mechanisms emphasize formal reporting, stage-gate controls, and compliance with predefined scope, cost, and time constraints.

However, research has long demonstrated that many projects operate under conditions of ambiguity and unforeseeable change. Pal et al. (2023) distinguish between uncertainty that can be addressed through planning and deeper forms of ambiguity where “events cannot be predicted”. Such environments exposed the limitations of rigid predictive control systems and contributed to the rise of agile methodologies.

Agile project management emerged as a response to volatility and complexity. Rather than assuming complete *ex ante* knowledge, agile models prioritize iterative development, adaptive planning, and distributed team autonomy (Karim Zadeh et al., 2024). Decision-making becomes more decentralized, with teams empowered to adjust priorities in short cycles. Nevertheless, despite this flexibility, accountability remains fundamentally human-centered. The project leader (or product owner,

scrum master) continues to mediate between strategic intent and operational execution, and governance mechanisms still rely on structured coordination, transparency rituals, and defined role responsibilities.

Hybrid models attempt to reconcile predictive stability with agile adaptability. These configurations combine formal planning structures with iterative execution mechanisms, particularly in complex organizational environments where strategic alignment and compliance requirements coexist with innovation pressures. Yet even in hybrid arrangements, governance frameworks maintain identifiable decision nodes, escalation paths, and managerial accountability structures.

Beyond methodological differences, project governance research emphasizes that projects are embedded within broader organizational and stakeholder systems. Governance serves to align projects with strategic objectives, ensure benefit realization, and manage stakeholder expectations (Too & Weaver, 2014). Multi-level governance structures connect portfolio management, program oversight, and individual project control. In all these configurations, the underlying assumption persists: decision authority, sensemaking, and responsibility are ultimately located in human actors.

Thus, despite methodological diversification, traditional project management models share three foundational assumptions. First, uncertainty can be managed through structured planning and adaptive correction. Second, governance relies on identifiable human accountability and role clarity. Third, decision-making authority is concentrated in formal managerial positions, even when operational flexibility increases.

These assumptions provide a stable conceptual baseline. The increasing integration of artificial intelligence into project environments raises a fundamental question: what happens when elements of forecasting, risk identification, prioritization, and monitoring are partially delegated to algorithmic systems? To address this question, the next section examines artificial intelligence in the broader context of management and organizational governance.

4 Artificial Intelligence in Management and Organizational Governance

Artificial intelligence is increasingly positioned as a transformative force in contemporary management. While early applications focused primarily on automation of repetitive tasks, recent developments extend AI's influence into cognitive domains traditionally associated with managerial judgment, including forecasting, prioritization, and strategic decision support (Einola & Khoreva, 2023). AI systems are commonly defined as technologies capable of “learning, interacting, and problem solving” (Einola & Khoreva, 2023), or as systems that “interpret external data, learn from such data, and use those learnings to achieve specific goals” (Di Vaio et al., 2020).

In management contexts, AI is most frequently associated with predictive analytics, pattern recognition, and optimization capabilities. Machine learning algorithms can analyze large volumes of historical and real-time data to identify trends, anticipate risks, and generate performance forecasts (Pal et al., 2023). Such systems increasingly function as decision-support mechanisms, enhancing estimation accuracy and resource allocation efficiency (Bento et al., 2022). In this sense, AI does not merely execute predefined rules but actively contributes to shaping managerial perception of risk, opportunity, and performance.

This shift has important governance implications. Traditional governance models assume that decision authority and accountability reside clearly within identifiable human actors. However, as AI-generated insights influence strategic and operational choices, the locus of epistemic authority becomes more distributed. Algorithmic systems increasingly determine which data are considered relevant, which patterns are recognized, and which scenarios are evaluated as optimal. As Cubric (2020, p. 1) notes, while economic drivers motivate AI adoption, barriers and social considerations include concerns related to “trust,” “dependence on non-humans,” and responsibility. These concerns directly intersect with governance questions regarding transparency and explainability of algorithmic decisions.

Moreover, AI integration is not confined to technical efficiency gains but reshapes organizational ecosystems. Research on human–AI co-existence emphasizes that AI solutions become embedded in workflows and influence how organizational members interpret their roles and responsibilities (Einola & Khoreva, 2023). Consequently, AI implementation entails not only technological adjustment but also managerial reconfiguration.

From a governance perspective, three dimensions are particularly relevant. First, decision-support transformation: AI alters how information is generated and interpreted prior to managerial judgment. Second, accountability complexity: when algorithmic recommendations inform decisions, responsibility becomes relational rather than purely individual. Third, transparency and legitimacy concerns: the opacity of certain AI models challenges established norms of explainable and auditable decision-making.

These developments suggest that AI should not be conceptualized merely as an operational tool but as a structural component influencing governance architectures. If projects are central vehicles of strategic execution, and if AI increasingly participates in forecasting, prioritization, and risk detection, then its implications for project governance require systematic examination. The next section, therefore, turns to the core analytical focus of this paper: the transition from traditional to AI-augmented project management and its consequences for project lifecycle processes and managerial roles.

5 From Traditional to AI-Augmented Project Management

The integration of artificial intelligence into project environments does not merely enhance existing practices; it gradually reconfigures the underlying decision-making logic of project management. Whereas traditional models rely on structured ex ante planning and human-centered authority, AI introduces dynamic, data-driven recalibration into core project processes. This shift represents not a methodological adjustment but a transformation of how projects are conceptualized, monitored, and governed.

5.1 Planning and Forecasting

In predictive project management, planning is primarily *ex ante*: objectives, timelines, budgets, and risks are defined before execution begins. AI challenges this static logic by enabling continuous forecasting based on evolving datasets (Pal et al., 2023). Machine learning models can detect emerging patterns in real time, recalculating risk probabilities and performance projections.

This transformation shifts planning from a one-time design activity toward an ongoing adaptive process. Rather than assuming forecast stability, AI-supported environments operate through iterative recalibration. Consequently, the position of epistemic authority begins to expand from the project manager's experiential judgment toward algorithmic pattern recognition.

5.2 Monitoring and Control

Traditional governance relies on formal reporting cycles, milestone reviews, and stage-gate approvals. Monitoring is episodic and mediated through managerial interpretation. AI-enabled analytics, however, allow real-time monitoring of performance indicators, resource utilization, and risk signals (Bento et al., 2022).

This shift reduces informational latency and increases analytical depth. Yet it also introduces governance complexity. When algorithmic systems continuously flag deviations or optimize resource allocation, managerial discretion becomes partially coordinated by algorithmic recommendations. Monitoring transforms from human evaluation of past performance into a hybrid human–algorithmic interpretation of live data streams.

5.3 Risk Identification and Uncertainty Management

Research distinguishes between manageable uncertainty and deeper ambiguity. AI extends the capacity to process large-scale historical data, potentially identifying risk patterns that exceed human cognitive limits. Predictive models can anticipate schedule overruns or resource holdups earlier than traditional approaches.

However, AI does not eliminate uncertainty; it reframes it. Algorithmic models operate on historical correlations, which may not fully capture unique or extraordinary events. Thus, while AI enhances risk detection within known data structures, it may simultaneously obscure forms of uncertainty not characterized in training datasets. The governance challenge, therefore, shifts from identifying risks to evaluating the reliability and boundaries of algorithmic suggestion.

5.4 Reconfiguring the Role of the Project Manager

Perhaps the most significant transformation concerns managerial roles. In traditional project management, the project manager functions as planner, coordinator, and primary decision authority. AI integration does not eliminate this role but adjusts its nature.

As algorithmic systems increasingly generate forecasts, prioritize alternatives, and monitor deviations, the project manager's role shifts from sole decision-maker toward orchestrator of hybrid intelligence. Rather than producing knowledge directly, managers interpret, validate, and contextualize AI-generated insights. Authority becomes relational rather than singular.

This reconfiguration introduces new competencies: data literacy, critical evaluation of algorithmic outputs, and ethical oversight. Simultaneously, accountability structures become more complex. When complex algorithmic models influence decisions, responsibility cannot be reduced to either human or machine alone. Governance instruments must therefore adapt to hybrid decision-making configurations.

Transitional Reflection

The transition from traditional to AI-augmented project management is not characterized by abrupt replacement but by gradual integration. Yet even partial integration reshapes planning logic, monitoring mechanisms, risk perception, and managerial identity. AI does not simply support project management; it actively shapes project reality.

This transformation raises a broader governance question: how should responsibility, transparency, and strategic alignment be structured in environments where algorithmic systems contribute to decision-making? The next section addresses this issue by revisiting project management through the lens of AI-augmented project governance.

6 AI-Augmented Project Governance: Conceptual Foundations and Implications

The preceding analysis demonstrates that AI integration does not merely refine project practices; it reshapes the underlying decision-making logic of project management. If planning becomes continuously recalibrated, monitoring becomes real-time and data-driven, and risk identification increasingly relies on algorithmic implication, then project governance cannot remain conceptually anchored in exclusively human-centered authority structures. A reconsideration of project governance is therefore required.

6.1 Reconfiguring Decision Authority

Traditional project governance frameworks assume clearly identifiable lines of authority and accountability. Decision rights are formally allocated, escalation paths are predefined, and responsibility is ultimately traceable to human actors (Too & Weaver, 2014). In AI-enabled environments, however, decision creation becomes hybrid. Algorithmic systems contribute to predictive assessments, scenario simulations, and optimization outputs that materially influence managerial judgment.

This does not imply that AI replaces human authority. Rather, it redistributes the locus of decision formation. Project managers increasingly operate within patterns where their discretion is shaped by algorithmic insights. Authority becomes relational: outcomes emerge from the interaction between human interpretation and machine-generated analysis. Consequently, governance systems must evolve from controlling individual decisions to governing hybrid decision processes.

6.2 Expanding Managerial Competencies

As the role of the project manager shifts from sole planner toward orchestrator of hybrid intelligence, new competencies become central. Beyond traditional skills in coordination and stakeholder management, project leaders must develop data literacy, critical evaluation of algorithmic outputs, and awareness of model limitations.

AI systems operate on historical datasets and probabilistic inference; they may reinforce biases embedded in data or obscure forms of uncertainty not captured in training sets (Cubric, 2020). Responsible project leadership, therefore, requires the capacity to question algorithmic recommendations rather than merely execute them. Managerial competence, therefore, extends beyond making decisions to critically assessing when and how AI-generated insights should be used.

6.3 Accountability and Transparency in Hybrid Environments

Perhaps the most significant governance effect concerns accountability. Traditional governance assumes a relatively direct alignment between decision-makers and outcomes. In AI-augmented environments, however, the opacity of algorithmic models complicates this alignment. If decisions are influenced by complex machine learning systems, responsibility cannot be simplistically attributed either to the system or to the individual manager.

Governance mechanisms must therefore incorporate transparency requirements, documentation of algorithmic inputs, and a clear definition of human oversight responsibilities. Without such adaptation, organizations risk a gap between formal accountability structures and actual decision dynamics. This challenge is particularly significant in project contexts aligned with ESG principles, where transparency, fairness, and ethical responsibility are increasingly scrutinized (Di Vaio et al., 2020).

6.4 Defining AI-Augmented Project Governance

Building on these considerations, this paper introduces the concept of *AI-augmented project governance*. AI-augmented project governance refers to governance configurations in which human actors maintain formal accountability while

algorithmic systems participate in shaping decision inputs, risk perceptions, and performance evaluations.

This configuration is characterized by:

1. Hybrid decision pattern (human–algorithmic interaction)
2. Distributed influence over planning, monitoring, and risk assessment decisions
3. Expanded managerial oversight responsibilities
4. Enhanced requirements for transparency and explainability

AI-augmented governance does not eliminate the human role. Rather, it reframes it. Managers remain accountable for decisions, yet their authority operates within algorithmically informed environments. Governance must therefore shift from controlling actions to governing interactions between human judgment and machine inference.

6.5 Boundary Conditions of AI-Augmented Project Governance

The proposed framework of AI-augmented project governance is unlikely to operate uniformly across all organizational and project contexts. Its effectiveness depends on several boundary conditions related to project complexity, organizational maturity, and governance capability.

First, AI-augmented governance is particularly relevant in large-scale, complex, and data-intensive project environments, where decision-making involves significant uncertainty, interdependence, and continuous monitoring requirements. Such contexts include digital transformation initiatives, infrastructure megaprojects, innovation-driven projects, and ESG-oriented transformation programs. In these environments, AI systems can provide analytical capabilities that exceed individual managerial cognition, particularly in forecasting, risk detection, and portfolio coordination.

Second, the implementation of AI-augmented governance requires a certain level of organizational maturity. Organizations must possess not only technological infrastructure but also governance capabilities related to data management, transparency, and managerial oversight. Low levels of digital maturity, weak

governance structures, or insufficient AI literacy may reduce the effectiveness of AI-supported decision processes and increase governance risks.

Third, the framework may be less applicable in small-scale or low-complexity projects where managerial intuition, implicit knowledge, and interpersonal coordination remain more significant than large-scale analytical processing. Similarly, highly creative or exploratory project environments may resist extensive algorithmic structuring due to the difficulty of codifying uncertainty and innovation dynamics into data-driven models.

These boundary conditions suggest that AI-augmented project governance should not be interpreted as a universal governance solution, but rather as a context-dependent governance configuration whose effectiveness varies according to organizational, technological, and project-specific characteristics.

6.6 Conceptual Framework of AI-Augmented Project Governance

To synthesize the conceptual transformation discussed throughout the paper, Figure 1 illustrates the transition from traditional project management toward AI-augmented project governance. The framework highlights how AI integration progressively reshapes planning logic, monitoring mechanisms, managerial authority, accountability structures, and ESG-oriented governance oversight.

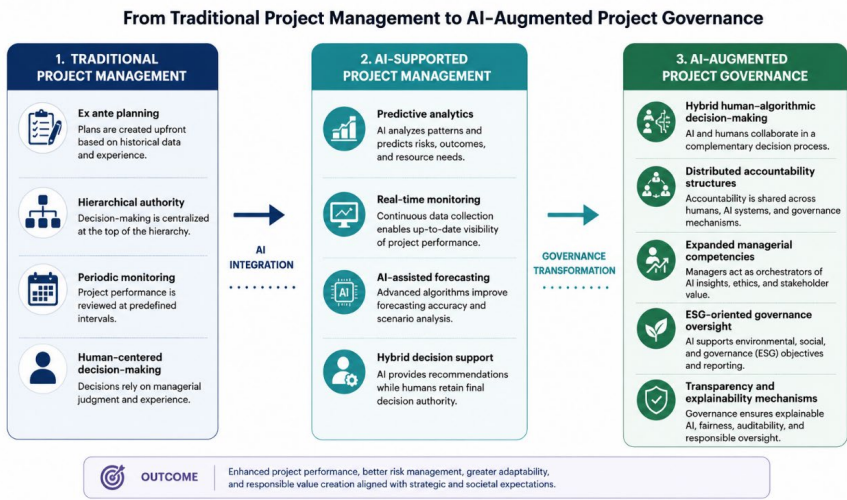


Figure 1: From Traditional Project Management to AI-Augmented Project Governance

7 Discussion: Opportunities, Challenges, and ESG Implications

The conceptual analysis developed in this paper suggests that AI integration in project environments presents both transformative opportunities and structural challenges. While AI enhances analytical capabilities, improves forecasting accuracy, and enables real-time monitoring, it simultaneously challenges established governance assumptions concerning authority, accountability, and transparency.

7.1 Opportunities for Enhanced Project Performance

AI-augmented project management offers significant performance-related advantages. Predictive analytics can improve estimation accuracy and resource allocation (Pal et al., 2023), while data-driven monitoring reduces informational latency and allows earlier detection of deviations. In complex project environments characterized by uncertainty and interdependence, algorithmic support may increase responsiveness and decision quality.

Furthermore, AI systems can enhance portfolio-level oversight by identifying cross-project patterns and systemic risks that exceed individual managerial cognition. In this sense, AI contributes not merely to operational efficiency but to strategic alignment and benefit realization, core objectives of project governance (Costantino et al., 2015).

7.2 Structural Challenges and Governance Risks

However, the integration of AI introduces structural challenges. First, the complexity of certain algorithmic models complicates the explainability and traceability of decisions. If project outcomes are influenced by complex machine learning systems, governance mechanisms must address how decisions can be justified and assessed.

Second, distributed decision authority may blur accountability boundaries. While human managers remain formally responsible, their judgments are increasingly shaped by algorithmic outputs. Without explicit governance adaptation, this hybrid decision model risks creating accountability gaps.

Third, overreliance on historical datasets may reinforce embedded biases or fail to capture unprecedented disruptions. As Cubric (2020) notes, social considerations - including trust and dependence on non-human systems - constitute significant barriers to AI adoption. In project contexts, such concerns may undermine stakeholder confidence if not proactively managed.

7.3 ESG Alignment and Responsible AI Governance

The relevance of these governance challenges becomes particularly relevant in relation to ESG principles. Sustainability-oriented projects increasingly require transparency, fairness, and long-term accountability. AI integration must therefore align not only with efficiency objectives but also with ethical standards and responsible innovation frameworks (Di Vaio et al., 2020).

AI-augmented project governance should incorporate mechanisms ensuring explainability, human oversight, and bias monitoring. This includes clear documentation of algorithmic inputs, defined escalation paths for influential automated recommendations, and structured review processes assessing the social implications of AI-informed decisions. In ESG-sensitive environments, responsible AI use becomes not merely a technical requirement but a governance obligation.

7.4 Practical and Managerial Implications

The findings of this paper suggest that organizations cannot approach AI integration in project environments solely as a technological implementation challenge. Instead, AI adoption requires governance redesign and managerial adaptation. As AI increasingly influences planning, monitoring, and risk evaluation processes, organizations must establish governance mechanisms capable of ensuring transparency, accountability, and responsible oversight.

For project managers, this implies the need for expanded competencies beyond traditional coordination and execution capabilities. Managers must develop AI literacy, critical interpretation skills, and the ability to evaluate the reliability and limitations of algorithmic recommendations. Effective project leadership in AI-enabled environments increasingly depends on balancing analytical augmentation with human judgment and ethical responsibility.

At the organizational level, governance structures should incorporate clearly defined oversight procedures for AI-informed decisions. This includes transparency mechanisms, review protocols for high-impact algorithmic recommendations, and clearly defined accountability structures specifying when human intervention or escalation is required. Such mechanisms become particularly important in ESG-sensitive project environments, where explainability, fairness, and long-term responsibility are critical governance expectations.

Ultimately, the successful integration of AI into project management depends not only on technological capability, but also on the ability of organizations to align governance structures, managerial roles, and ethical standards with emerging forms of hybrid human–algorithmic decision-making.

7.5 Theoretical Contribution

The primary theoretical contribution of this paper lies in reframing AI in project management not as a tool-level enhancement but as a governance-level transformation. By introducing the concept of AI-augmented project governance, the study extends existing literature that has largely focused on performance optimization and technical implementation. It shifts the analytical lens toward decision authority, accountability structures, and managerial identity in hybrid human–algorithmic systems.

Rather than replacing managerial authority, AI changes how decisions are shaped and governed in project environments. This perspective opens new opportunities for research examining how project-based organizations can design governance systems that remain strong under conditions of algorithmically informed decision-making.

8 Conclusion

This paper has conceptually examined the transition from traditional to AI-augmented project management within the broader context of digital and sustainability-driven transformation. By synthesizing insights from project management, governance theory, and artificial intelligence research, the study argues

that AI integration does not merely enhance operational efficiency but reshapes the underlying logic of decision-making in project environments.

The analysis demonstrates that AI influences planning, monitoring, and risk management processes in ways that redistribute decision formation across human and algorithmic actors. As a result, traditional governance assumptions - centered on clearly defined human authority and accountability - require reconsideration. In response, the paper introduces the concept of *AI-augmented project governance* to capture governance configurations in which human actors retain formal responsibility while algorithmic systems significantly shape decision inputs and performance evaluations.

The main theoretical contribution of this study lies in reframing AI in project management as a governance-level transformation rather than a purely technical enhancement. By focusing on decision authority, accountability structures, and managerial roles, the paper extends existing literature that has primarily emphasized performance optimization and tool implementation.

This study is inherently conceptual and does not provide empirical validation of the proposed framework. Future research should therefore investigate AI-augmented governance through empirical case studies, longitudinal analyses, and comparative research across industries and project types. In particular, research is needed to examine how organizations design oversight mechanisms, define accountability boundaries, and ensure ESG alignment in hybrid human–algorithmic project environments.

Future research should further explore the organizational implications of AI-augmented project governance through empirical and comparative studies. Longitudinal case studies could examine how governance structures evolve during different phases of AI integration in project environments. Cross-industry comparisons may provide insight into how AI-enabled governance differs across digital transformation projects, infrastructure megaprojects, innovation initiatives, and ESG-oriented programs.

Additionally, future insights could focus on developing governance maturity models capable of assessing organizational readiness for AI-augmented project management. Another promising avenue involves the development of measurement scales for evaluating AI governance capability, managerial AI literacy, and organizational oversight effectiveness in hybrid human–algorithmic environments. Such research would contribute to translating conceptual governance frameworks into empirically operationalized models suitable for organizational practice and further theoretical development.

As AI continues to pervade project-based organizations, the critical question is no longer whether AI will influence project management, but how governance structures can evolve to ensure that technological augmentation strengthens - rather than undermines - responsible and sustainable managerial practice.

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DEVELOPMENT OF A MODEL FOR MEASURING THE QUALITY OF CORPORATE GOVERNANCE IN INSURANCE GROUPS IN THE CONTEXT OF CROSS-BORDER OPERATIONS

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Insurance companies play a systemic role in capital allocation and sustainable risk management, making corporate governance quality crucial for financial stability. This study develops a comparative Corporate Governance Index (CGI) for insurers, positioning ESG as its central analytical pillar. The model is structured around five dimensions: board composition and functioning, transparency and disclosure, shareholder rights, ESG integration, and the organisation of key functions under Solvency II. Using panel data for 2014–2024 covering insurers in Slovenia and selected South-East European countries, with particular focus on the Triglav and Sava Re groups, the research applies correlation and multivariate regression analysis to test the relationship between CGI values, ESG integration, company size, and market development. The findings conceptualise ESG as a structural determinant of governance quality rather than merely a reporting practice and offer a practical analytical tool for regulators and corporate decision-makers.

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1 Introduction

Corporate governance is a key mechanism for ensuring stability, transparency, and long-term sustainability in insurance companies, which manage policyholders' funds and are exposed to significant systemic risks. Over the past decade, governance in the insurance sector has increasingly been shaped by cross-border operations, more demanding regulatory requirements, and the growing importance of environmental, social, and governance (ESG) factors. While the existing literature addresses individual aspects of corporate governance, comprehensive empirical models at the level of insurance groups—particularly in South-East Europe—remain relatively scarce.

This paper develops a scientifically grounded model for measuring corporate governance quality in cross-border insurance groups. A composite Corporate Governance Index (CGI) is constructed to enable systematic comparison across insurers of different sizes and institutional settings. Using panel data for the period 2014–2024 covering insurers in Slovenia and selected South-East European countries, the analysis examines the relationship between governance quality, insurer size, market development, and ESG integration. The findings reveal meaningful differences between parent companies and subsidiaries within insurance groups and confirm the significant role of the institutional environment in shaping governance outcomes.

2 Theoretical Background / Literature review

Effective corporate governance underpins the successful operation of insurance companies. It contributes to ensuring the stability and long-term solvency of business entities, while safeguarding the interests of all institutional stakeholders within the insurance sector. Given that insurers act as financial intermediaries managing policyholders' funds, a high degree of accountability, transparency, and integrity is fundamental to their operations. Furthermore, a robust and well-designed governance framework is vital for the efficacy of internal control mechanisms and the strengthening of capital adequacy, thereby fostering confidence among investors, supervisory authorities, and the wider public.

Corporate governance regulates the relationships between various stakeholders within a company. It combines mandatory rules, best practice recommendations, and internal acts of the company, such as statutes, articles of association, and codes. Self-regulation is also gaining importance, as it enables companies to design their own methods of organisation, oversight, and accountability (Jovanović et al., 2024).

In a broader sense, corporate governance encompasses two aspects: internal, which refers to the relationships among the company's governing bodies, and external, which describes how the company and its bodies interact with shareholders and other external stakeholders (Jovanović and Bratina, 2016).

Corporate governance structures the relationships between management and supervisory boards, shareholders, and other stakeholders. It further defines the organisational framework that supports the pursuit of corporate objectives, determines the means of attaining them, and establishes performance monitoring mechanisms. Its fundamental purpose is to foster an environment of trust, transparency, and accountability, which facilitates long-term investment, contributes to financial stability, and promotes business integrity, thereby supporting sustainable economic growth and broader societal development (Bratina et al., 2024).

In insurance companies, corporate governance is not a mere formality but a precisely engineered framework. It strengthens the independence of key functions, strictly defines the powers and responsibilities of management and supervisory boards, and enables effective risk management. Robust governance within an insurer allows for more than just profit-seeking; it operates in the interest of policyholders, contributes to the stability of the financial system, and bolsters public confidence (Kramarić et al., 2018).

The insurance sector plays a significant role in the overall economy, which is also reflected in the development of a specific legal field known as insurance corporate law. This field prescribes how insurance companies must be organised and how the supervision of their operations is conducted. One of its distinctive features is the emphasis on corporate governance, which must be clearly established and effective within an insurer. Since insurance companies operate in the interest of policyholders and collect premiums in advance of potential losses, they bear a particularly high degree of responsibility. Consequently, they must ensure robust and reliable

mechanisms for oversight, reporting, and compliance. In this regard, the management and supervisory boards play a pivotal role, being responsible for ensuring that the system operates transparently and in the interest of policyholders (Petrović Tomić, 2021).

Corporate governance represents a system of relationships between shareholders, management and supervisory bodies, and other company stakeholders, whereby broader definitions also encompass the role of employees in governance. Alongside business ethics and social responsibility, it contributes significantly to economic efficiency, economic growth, and investor confidence. An effective governance system reduces the cost of capital, promotes the rational use of resources, and supports company development, while simultaneously influencing the performance of the entire economy. Therefore, the legal framework for corporate governance must allow for the flexible integration of various interests and provide the conditions for stable and sustainable operations (Bohinc, 2016).

The governance of insurance companies is more demanding than that of other business entities, as they operate in a more complex environment and are accountable to a broader range of stakeholders. In addition to the interests of shareholders, they must also take into account the interests of policyholders, employees, supervisory authorities, and tax authorities. This necessitates more prudent, coordinated, and responsible decision-making in management (Elamer et al., 2018).

Driven by the rise in investments based on ESG criteria, providing relevant, high-quality, and comparable ESG data has become a primary task for companies. Such data enables investors to make informed capital allocations, as it serves as a signal of a company's genuine commitment to sustainable development and reduces information asymmetry between firms and financial markets. Consequently, high-quality ESG reporting represents more than just a regulatory obligation; it constitutes a mechanism for channelling capital into sustainable investments and supporting long-term economic, environmental, and social goals (Jovanović and Jovanović, 2022).

Empirical analyses systematically addressing the actual effects of corporate governance structures within the insurance sector remain scarce, particularly in the context of the cross-border operations of insurance groups, where subsidiaries function in diverse legal, regulatory, and market environments. Existing studies predominantly focus on individual insurers as the primary units of analysis and seldom address internal intra-group relationships (specifically the dynamic between the parent company and its subsidiaries), the transfer of governance policies, or the degree of their actual implementation at the group level.

Selected authors are cited and analysed in further detail below.

Chiaromonte et al. (2020) observe that the sustainable practices of insurance companies, as measured by ESG scores, are linked to enhanced financial stability and lower insolvency risk. Utilising a sample of 94 listed insurers between 2006 and 2018, the authors demonstrate a statistically significant positive correlation between the aggregate ESG score and stability, measured by the (log) Z-score. When decomposing ESG into individual pillars, the stability effect is predominantly attributed to the Environmental (E) and, most significantly, the Social (S) pillars; conversely, the Governance (G) pillar was not statistically significant in their primary specifications, a finding the authors attribute to the high degree of existing regulation and oversight within the insurance sector. These results remain robust after controlling for endogeneity and selection bias (e.g., via ESG instrumenting and the Heckman procedure). Furthermore, the authors identify heterogeneity across business lines: the positive ESG–stability relationship is more pronounced in life insurance than in non-life insurance.

Gatzert et al. (2020) examine sustainable (ESG) risks and opportunities within the insurance industry, emphasising that these cannot be reduced solely to climate-related risks. Adopting the methodology of a structured review, the authors systematically categorise relevant ESG risks and opportunities across the asset side, the liability side, and the broader corporate perspective. For each category, they present strategic approaches for insurers to address these factors, complemented by empirical insights from existing literature and (industry) surveys of current practices, with a primary focus on the European market. The authors highlight that ESG factors materialise on both sides of the balance sheet: on the asset side primarily through market and credit transition effects (e.g., investment revaluation and shifting

regulatory expectations), and on the liability side through changes in the insurance risk profile (including the frequency and intensity of claims, modelling accuracy, and reserving requirements).

Apicella et al. (2025) conceptualise ESG reputational risk in insurance as a stakeholder-driven phenomenon rooted in policyholders' subjective beliefs and behavioural biases. Arguing that reputation is built upon the expectations of external observers, the authors develop a formal valuation framework in which policyholders' judgements shape reputational scores, potentially influencing insurer behaviour through a self-reinforcing feedback mechanism. In a numerical application based on Bloomberg ESG data and a sample of 29 insurers from the STOXX Europe 600 index, the authors demonstrate that higher ESG scores do not necessarily result in stronger reputation-driven incentives; rather, the effects depend on stakeholder preferences regarding specific pillars and the perceived relevance of the Environmental (E), Social (S), and Governance (G) dimensions.

In a report for the NYU Stern Center for Sustainable Business / Rockefeller Asset Management, Whelan et al. (2021, see also the extended version co-authored by Tracy Van Holt) conducted an extensive evidence review of the link between ESG and financial performance, aggregating findings from over 1,000 studies published between 2015 and 2020. In their analysis, study results were categorised—rather than undergoing a conventional meta-analysis of a single 'effect size'—based on whether they addressed corporate performance or portfolio investment performance, with outcomes subsequently coded as positive, neutral/mixed, or negative. They found that in the vast majority of reviewed studies, ESG was typically positively, or at least not negatively, correlated with financial performance. They further emphasised that these effects are often more pronounced over longer time horizons and that a high level of disclosure alone is generally insufficient without the substantive integration of ESG into strategy and risk management.

Di Tommaso and Mazzuca (2023) extended this inquiry to the capital markets, investigating whether ESG rating information is reflected in the share prices of European insurance companies. Methodologically, they employed an event study approach (measuring Cumulative Abnormal Returns – CAR around the announcement of ESG rating changes), distinguishing between rating upgrades and downgrades. Utilising a dataset of insurers included in Refinitiv ESG Europe, they

linked daily ESG rating time series (2011–2021) with daily share prices from Datastream (expressed in EUR). The final sample encompassed 56 insurers from 15 countries and 210 rating change announcements (72 downgrades, 138 upgrades). They found that the market reacted with statistical significance to such announcements: upgrades were associated with share price appreciation, while downgrades led to depreciation. Notably, investor sensitivity was more pronounced in the period preceding the Paris Agreement (2015–2016). Additionally, they showed that the Environmental (E) pillar is of paramount importance to investors, as the market response was particularly strong following a decline in environmental scores compared to the social or governance pillars. The authors conclude that this confirms the presence of market discipline: ESG signals can either "reward" or "penalise" insurers, which has direct implications for corporate governance (specifically regarding proactive climate risk management and credible disclosures).

Carannante et al. (2024) analyse how corporate ESG reputation influences the formation of a "sustainability premium" in the insurance sector—namely, a price markup that insurers can justify through policyholders' perceived commitment to sustainability. The authors develop a formal theoretical framework based on behavioural economics (prospect theory), treating ESG reputation as a function of stakeholders' subjective perceptions and behavioural biases. This contribution is particularly relevant to corporate governance in insurance, as it underscores that ESG is not merely a matter of compliance or disclosure but is becoming an economically relevant factor in pricing, reputation management, and long-term value creation. This is especially challenging for cross-border insurance groups due to the heterogeneous perceptions and expectations of stakeholders across different markets.

Sood and Özen (2024) conducted a systematic literature review (SLR) on ESG in the insurance industry using the PRISMA methodology, aiming to comprehensively assess the role of ESG in achieving sustainability. Based on a review of 35 scientific papers published between 2013 and 2023, they found that ESG factors increasingly influence all key segments of the insurance business, particularly investment decisions, risk management, product design, and the valuation of assets and liabilities. The authors emphasise that ESG transcends mere disclosure requirements to become a strategic element of corporate governance, with the Governance (G)

dimension playing a critical role in ensuring the fair treatment of policyholders and effective risk oversight.

In a conceptual paper, Clément et al. (2022) critically examined the use of ESG ratings as a proxy for measuring corporate sustainability. They argued that existing ESG methodologies primarily measure financial risk associated with ESG issues rather than sustainability in terms of sustainable development and the actual impact of companies on the environment and society. Based on an extensive literature review, the authors demonstrated that ESG ratings fail to capture key sustainability concepts, such as temporality, actual impact, resource management, and system interconnectivity; furthermore, they suffer from a lack of transparency, comparability, and consistency between rating agencies.

Al Qubaisi (2021) empirically investigates the impact of sustainable practices on the financial performance of insurance companies. Using multi-year panel data and a sample of insurers from various countries, the author analyses the link between ESG indicators (the aggregate ESG score and the E, S, and G pillars) and key financial metrics such as ROA, ROE, profitability, and liquidity. Methodologically, the study employs fixed-effects regression models to control for unobserved firm characteristics and other firm-specific factors (size, leverage, investment structure). The findings indicate a positive and statistically significant correlation between ESG and the financial performance of insurers, with the Social (S) and Governance (G) pillars proving particularly significant. The results suggest that the quality of corporate governance functions as a vital conduit through which sustainable practices generate economic effects, as superior governance mechanisms reinforce the positive impact of ESG on business outcomes.

In his work, Khovrak (2020) presented an ESG-oriented approach to insurance management, treating sustainability as an integral part of strategic and operational governance rather than an adjunct to compliance or reporting. The author theoretically argued that traditional approaches to insurance management overemphasise financial indicators, while ESG factors—particularly environmental and social ones—heavily influence risks, profitability, and business resilience. Based on an analysis of secondary sources, he proposed an ESG integration model involving (i) the identification of material ESG risks and opportunities, (ii) their incorporation into risk management processes, insurance product policies, and

investment strategies, and (iii) the establishment of monitoring systems and performance indicators aligned with sustainability goals.

Pfeifer (2021) addressed the role of Environmental, Social, and Governance (ESG) factors in insurance from the perspective of holistic risk management and solvency. The author emphasised that ESG no longer represents a peripheral reporting area or a voluntary sustainability initiative but is becoming an integral part of corporate governance and prudential supervision. Methodologically, the paper is based on a conceptual and regulatory-oriented analysis linking the existing Solvency II framework, supervisory expectations (particularly those from EIOPA), and the practical challenges of modelling long-term sustainability risks. Pfeifer notes that traditional actuarial and risk models are often not adapted to capture complex and long-term ESG risks, especially climate-related and reputational ones, necessitating an upgrade of data foundations, methodologies, and internal controls. A key finding is that the quality of corporate governance in insurance is increasingly judged by the ability to integrate ESG into strategic decision-making, risk management, and capital planning, rather than just formal compliance with rules.

Gatzert and Reichel (2024) analysed the development of sustainable investing in the US and European insurance industries using a text-mining approach to examine how insurers themselves (in public documents) address ESG and sustainable investment practices. Methodologically, they developed a dictionary of sustainable investment principles, criteria, terminology, and strategies, applying it to an extensive corpus of 1,215 annual, sustainability, and investment reports from 77 large insurers between 2013 and 2018, while also differentiating the quality of reporting. They found that both the proportion of insurers reporting on sustainable investing and the volume of such disclosures have significantly increased over time. Typically, insurers that disclose sustainable investment practices tend to be larger in scale; furthermore, European firms exhibit a markedly higher intensity of reporting compared to their counterparts in the United States.

Brogi et al. (2022) researched the determinants of "ESG awareness" in the insurance sector—the degree to which insurers recognise and integrate ESG aspects into their business policies. Using a sample of 107 large, listed US insurers from 2010 to 2018, they first defined "ESG awareness" as the dependent variable via a scoring model (assigning indicators for the presence of specific ESG policies). Subsequently, they

utilised fractional regression to analyse which financial characteristics (size, profitability, and solvency) were statistically associated with this ESG score. They found that size and profitability were the primary positive determinants of higher ESG awareness, while solvency as a proxy for financial strength also contributed, although less consistently throughout the tested models. Their findings remain robust under alternative specifications, confirming that larger, more solvent, and more profitable insurers are swifter in adopting and implementing ESG policies; this indicates a significant correlation between organisational capacity and the aptitude for ESG integration. The authors highlight that this connection is not limited to the aggregate ESG score but persists across the individual pillars (Environmental, Social, and Governance), suggesting that financial strength and firm size facilitate a broader adoption of sustainable practices.

The aforementioned research demonstrates that ESG factors and sustainability reporting significantly influence the perceived performance, stability, and reputation of insurance companies. However, existing knowledge reveals a critical research gap: there is a lack of comprehensive empirical analyses addressing the link between ESG and corporate governance at the level of insurance groups, particularly within a cross-border environment.

Research at the insurance group level is of paramount importance because key decisions regarding governance, risk, and ESG strategies are made centrally, while their execution occurs within subsidiaries operating in diverse legal and market environments. This cross-border structure can create discrepancies between formally defined group policies and their actual implementation at the local level. Differences in market development, supervisory practices, and degrees of ESG maturity can lead to inconsistent governance practices and non-comparable disclosure quality, which in turn impacts the overall performance of governance and risk management across the group. Therefore, an analysis of insurance groups allows for a more realistic assessment of corporate governance quality and the development of methodological tools that reflect the complexities of cross-border operations.

Building on the theoretical insights presented in the previous section, the following methodology translates established corporate governance and ESG concepts into an empirically testable model applicable to cross-border insurance groups.

3 Methodology

This research adopts a quantitative, comparative, and longitudinal approach, aimed at analysing the quality of corporate governance within insurance groups operating across diverse legal, institutional, and market environments. The hallmark of this methodological framework lies in its group-level focus rather than an analysis of individual insurers. This facilitates a comprehensive assessment of governance structures, internal control mechanisms, and the cross-border transfer of governance practices within a group of subsidiaries across various jurisdictions.

The empirical analysis is based on panel data spanning the period 2014–2024 and encompasses insurance companies operating within cross-border groups, with a specific focus on the Triglav and Sava groups in Slovenia and the countries of South-East Europe. Such an approach allows for the comparison of governance models both within and between groups, while simultaneously accounting for the impact of differing national regulatory regimes, levels of insurance market development, and institutional frameworks. Group-level analysis thus provides a more realistic assessment of corporate governance quality in a cross-border context, where key governance functions, risk policies, and ESG strategies are often determined centrally at the group level, while their implementation varies among individual subsidiaries.

The first stage of the research involves the development of a novel composite Corporate Governance Index (CGI). The CGI developed in this paper is a new, purpose-built, sector-specific composite index designed explicitly to assess the quality of corporate governance in insurance companies and insurance groups. Although the concept of a corporate governance index is well established in the literature, existing CGI models differ significantly in scope, structure, weighting, and indicator selection, reflecting the specific objectives, industries, and institutional environments of individual studies. The CGI applied in this research is therefore not a replication of an existing index, but an original construct that selectively draws on established governance principles while adapting them to the regulatory and organisational specificities of the insurance sector.

The selection of the five CGI pillars is grounded in both theory and regulation. The structure and functioning of management and supervisory bodies, transparency and disclosure, and shareholder rights represent the core, traditionally recognised pillars of corporate governance across jurisdictions. These are complemented by two insurance-specific pillars: the integration of ESG factors and the organisation of key functions under Solvency II. ESG is treated as an autonomous governance pillar because contemporary research and supervisory expectations increasingly recognise sustainability, stakeholder orientation, and ethical conduct as integral elements of governance quality rather than merely as reporting obligations. Key functions under Solvency II are included to capture the prudential and control dimensions of insurance governance, which do not exist in a comparable form in non-financial sectors.

The choice of individual indicators within each pillar follows three guiding principles: relevance, comparability, and data availability. Indicators were selected only if they (i) reflect governance practices with a clear theoretical or regulatory justification, (ii) can be consistently observed across countries and subsidiaries, and (iii) are based exclusively on publicly available information to ensure the transparency and replicability of the index. ESG indicators were deliberately limited to governance relevant sustainability attributes – such as formal commitments to sustainability, ethical codes, employee representation, and disclosure of social policies—rather than outcome-based or externally rated ESG scores, which vary substantially between providers and methodologies. This approach ensures that the ESG component of the CGI captures the institutionalisation of sustainability within governance structures, rather than market perceptions or rating-specific effects.

Each pillar is operationalised through binary and ordinal indicators normalized to a 0–1 scale and equally weighted. Equal weighting is applied to avoid introducing subjective bias regarding the relative importance of individual governance dimensions and to preserve transparency of the index construction. As a result, the CGI provides a structured, internally consistent, and methodologically robust instrument for comparative analysis of corporate governance quality within and across cross-border insurance groups.

In the second stage, a descriptive and comparative analysis is conducted, enabling a comparison of CGI values between parent companies and subsidiaries within individual insurance groups, as well as between countries with varying degrees of institutional development.

The third stage employs correlation and multivariate regression analyses to examine the associations between the CGI and selected explanatory variables, such as insurer size, insurance market development (penetration, density, premium volume), and the level of ESG integration.

This methodological framework facilitates a systematic and comparable assessment of corporate governance quality within cross-border insurance groups. Furthermore, it addresses a significant research gap in the existing literature, which predominantly focuses on individual insurers and often overlooks the complexities of group-level structures.

The statistical analysis, comprising the calculation of correlation coefficients and the estimation of regression models, was performed using the open-source statistical software R (R Core Team). Pearson correlation coefficients were utilised to assess linear associations between the CGI and its respective sub-indicators, with statistical significance verified through a two-tailed t-test testing the null hypothesis of no linear relationship between the variables. The regression analysis was conducted using linear and panel data regression models, which allow for the incorporation of the temporal dimension of the data as well as unobserved characteristics of individual insurers. This approach ensures methodological transparency, reproducibility of results, and alignment with best practices in empirical research.

The CGI consists of five thematic sub-indicators:

1. Indicator of the structure of governing and supervisory bodies
2. Transparency and disclosure index
3. Shareholder rights index
4. Corporate social responsibility index (ESG)
5. Key functions index under Solvency II

Each sub-index consists of several criteria that have been normalized to an interval from 0 to 1. The final CGI is calculated as the arithmetic mean of all five sub-indices:

CGI_{it} = (GOV_{it} + DISC_{it} + SHR_{it} + ESG_{it} + KF_{it}) / 5, where:

- CGI_{it} = the composite corporate governance index of insurance company *i* in year *t*;
- GOV_{it} = index of the structure of management and supervisory bodies;
- DISC_{it} = transparency and disclosure index;
- SHR_{it} = shareholder rights index;
- ESG_{it} = ESG indicator;
- KF_{it} = indicator of key functions under Solvency II.

All sub-indicators are normalized to the interval from 0 to 1, therefore the value of the CGI index also lies in the interval: $0 \leq \text{CGI}_{it} \leq 1$.

To enhance analytical clarity, the Corporate Governance Index (CGI) is operationalised as a composite measure based on five equally weighted governance pillars: board structure and functioning, transparency and disclosure, shareholder rights, ESG integration, and key functions under Solvency II. Each pillar is constructed using clearly defined binary and ordinal indicators derived exclusively from publicly available disclosures, ensuring the transparency, comparability, and replicability of the model. Independent variables are operationalised as follows: insurer size is measured by total gross written premiums, while market development is captured through insurance penetration and premium density at the national level. ESG integration is treated not merely as a disclosure variable but as a governance attribute reflecting the formal institutionalisation of sustainability within corporate governance structures. This operationalisation allows the CGI to capture both traditional governance mechanisms and emerging sustainability-related governance dimensions in a unified analytical framework.

Table 1: Indicators by Sub-indices

Governance Structure Indicator (GOV)

Measure / question	Code	Description
Disclosure of company bodies (management and supervisory board)	GOV_BODY_DISC	1 The company publicly discloses the composition of the management and supervisory boards (e.g., in the annual report or on the website) with key information on members; 0 The composition is not disclosed or information is incomplete.
Gender diversity in management board	MB_GENDER_DIV	1 At least one female member in the management board; 0 No female member.
Gender diversity in supervisory board	SB_GENDER_DIV	1 At least one female member in the supervisory board; 0 No female member.
Disclosure of CVs of board members	GOV_CV_DISC	1 CVs of management and/or supervisory board members are publicly disclosed; 0 CVs are not disclosed or are insufficient.
Disclosure of appointment dates of board members	GOV_DATE_DISC	1 Appointment dates of board members are disclosed; 0 Not disclosed or incomplete.
Disclosure of responsibilities of board members	GOV_RESP	1 Responsibilities of individual board members are publicly disclosed; 0 Not disclosed.
Independence of supervisory board members	SB_INDEP	1 The company discloses which supervisory board members are independent; 0 Not disclosed.
Supervisory board self-assessment	SB_SELFASS	1 The company states that the supervisory board performs regular self-assessments; 0 Not disclosed.

Transparency and Disclosure Indicator (DISC)

Measure / question	Code	Description
Disclosure of management remuneration	MB_REM_DISC	1 Individual remuneration disclosed; 0.5 aggregate only; 0 not disclosed.
Disclosure of supervisory board remuneration	SB_REM_DISC	1 Individual remuneration disclosed; 0.5 aggregate only; 0 not disclosed.
Publication of periodic reports	PER_REPORT_DISC	1 At least semi-annual or quarterly reports published; 0 not available.
Disclosure of management shareholdings	MB_SHARE_DISC	1 Individual shareholdings disclosed; 0.5 aggregate; 0 not disclosed.
Disclosure of supervisory board shareholdings	SB_SHARE_DISC	1 Individual shareholdings disclosed; 0.5 aggregate; 0 not disclosed.
Related-party transactions disclosure	REL_PARTY_DISC	1 Fully disclosed; 0.5 aggregate disclosure; 0 not disclosed.
Publication of company statute/articles	STAT_DISC	1 Statute publicly available on website; 0 not available.

Measure / question	Code	Description
Ownership structure disclosure	OWN_DISC	1 Ownership structure including top 5 shareholders disclosed; 0 not disclosed or incomplete.
Financial calendar disclosure	FIN_CAL	1 Financial calendar published; 0 not published.
Corporate governance chapter in annual report	CG_CHAP	1 Separate CG chapter included; 0 not included or fragmented.
Strategy disclosure on website	STRAT_DISC	1 Strategy information publicly available; 0 not available.

Shareholder Rights Indicator (SHR)

Measure / question	Code	Description
Disclosure of shareholder rights	SH_RIGHTS_DISC	1 Rights publicly disclosed; 0 not disclosed.
Dividend information and policy	DIV_DISC	1 Dividend policy disclosed; 0.5 dividend info only; 0 not disclosed.
Investor relations officer	IRO_EXIST	1 IR officer/department publicly disclosed; 0 not disclosed.
Equal access to AGM information	SH_INFO_ACC	1 Equal access to AGM agenda and proposals; 0 not available or selective.
Disclosure of AGM resolutions	GM_DISC	1 Resolutions publicly disclosed; 0 not disclosed.

ESG Indicator (ESG)

Measure / question	Code	Description
Employee representative in management board	EMP_REP_MB	1 Employee representative present; 0 not present.
Employee representative in supervisory board	EMP_REP_SB	1 Employee representative present; 0 not present.
Commitment to sustainability	SUS_COMMIT	1 Explicit commitment disclosed; 0 not disclosed or only marginally.
HR policy disclosure	HR_POL	1 HR policy publicly disclosed; 0 not disclosed.
Social engagement activities	SOC_ENG	1 Activities disclosed (donations, sponsorships, etc.); 0 not disclosed.
Code of ethics	ETH_CODE	1 Code of ethics published; 0 not disclosed.

Key Functions under Solvency II Indicator (KF)

Measure / question	Code	Description
All four key functions disclosed	KF_ALL	1 All four functions disclosed; 0.5 partially disclosed; 0 not disclosed.
External auditor – Big 4	AUD_BIG4	1 Auditor is Big 4; 0 not Big 4.
Audit committee established	AC_EXIST	1 Audit committee established; 0 not established or not disclosed.

Source: Author's own construction of indicators.

Table 2: Comparative Table of CGI and Sub-Indicators – Slovenian Insurance Companies (2014–2024, by Rank)

Rank	Insurance company	Governance structure	Transparency	Shareholder rights	ESG	Key functions	CGI
1	Triglav Ljubljana	0.99	0.99	0.98	0.98	0.99	0.99
2	Vzajemna	0.97	1.00	1.00	1.00	1.00	0.99
3	Modra	0.91	0.89	0.91	0.91	0.97	0.92
4	Sava Maribor	0.79	0.79	0.79	0.79	0.79	0.79
5	Prva osebna	0.77	0.77	0.80	0.80	0.77	0.78
6	Vita	0.76	0.76	0.79	0.79	0.79	0.77
7	Merkur	0.74	0.71	0.71	0.77	0.80	0.75
8	Grawe	0.71	0.71	0.71	0.69	0.71	0.71
9	Generali	0.65	0.65	0.67	0.67	0.67	0.66

Source: Author's own calculation

The comparative analysis of Slovenian insurance companies based on Corporate Governance Index (CGI) scores indicates a relatively high overall standard of governance within the Slovenian insurance market. Triglav Ljubljana and Vzajemna occupy the top tier of the rankings, achieving the highest CGI values; this performance is attributed to their superior levels of transparency, sophisticated governance frameworks, and robust institutional integration. Both insurers demonstrate balanced and high scores across all sub-indicators, particularly regarding transparency, ESG integration, and key functions as mandated by the Solvency II Directive.

The middle segment comprises Modra, Sava Maribor, Prva osebna, and Vita, which achieve CGI values ranging approximately between 0.77 and 0.92. These companies are characterised by a relatively uniform distribution of scores across all sub-indicators, with no notably deficient areas. Their results reflect a stable quality of corporate governance, albeit slightly below the level of the market leaders.

Merkur, Grawe, and Generali are positioned in the lower segment, where CGI values are somewhat lower, primarily due to reduced scores in transparency or ESG integration. Nevertheless, these insurers still achieve relatively high CGI values, which points to a generally well-developed governance environment across the Slovenian insurance sector.

The findings confirm that higher CGI values are positively correlated with greater institutional integration, enhanced transparency, and a more comprehensive incorporation of ESG factors into the business and governance processes of insurance companies.

Table 3: CGI and Sub-indicators – Triglav Group (2014–2024)

Insurance company	Governance structure (GOV)	Transparency (DISC)	Shareholder rights (SHR)	ESG	Key functions (KF)	CGI
Triglav Ljubljana	0.99	0.99	0.98	0.98	0.99	0.986
Triglav Zagreb	0.86	0.88	0.85	0.87	0.89	0.870
Triglav Beograd	0.80	0.82	0.79	0.81	0.83	0.810
Triglav Sarajevo	0.78	0.80	0.77	0.79	0.81	0.790
Triglav Banja Luka	0.76	0.78	0.75	0.77	0.79	0.770
Lovćen (Montenegro)	0.79	0.81	0.78	0.80	0.82	0.800
Triglav Non-Life Skopje	0.74	0.76	0.73	0.75	0.77	0.750
Triglav Life Skopje	0.75	0.77	0.74	0.76	0.78	0.760

Source: Author's own calculations based on publicly available data disclosed in the published annual reports of the Triglav Group.

The data presented in the table indicates that the Triglav Group maintains a consistently high and comparable standard of corporate governance across all its subsidiaries. The parent company, Triglav Ljubljana, attains the highest score, reflecting its sophisticated governance frameworks, superior transparency, and robust ESG integration. While the subsidiaries record slightly lower index values, these remain relatively uniform; the observed disparities are primarily attributable to the varying levels of maturity in national markets and their respective institutional environments. Higher scores among the subsidiaries are characteristic of those operating in more advanced markets, whereas lower values are found in companies active within less developed or institutionally more heterogeneous environments. These findings underscore the significant influence of the institutional context on the quality of corporate governance, even within the confines of a single insurance group.

Table 4: Sub-Indicators – Sava Group (2014–2024 average)

Insurance company	Governance structure	Transparency	Shareholder rights	ESG	Key functions	CGI
Sava Maribor	0.79	0.79	0.79	0.79	0.79	0.79
Sava Beograd Non-Life	0.68	0.70	0.67	0.69	0.71	0.69
Sava Beograd Life	0.67	0.69	0.66	0.68	0.70	0.68
Sava Montenegro	0.69	0.71	0.68	0.70	0.72	0.70
Sava Kosovo	0.65	0.67	0.64	0.66	0.68	0.66

Source: Author's own calculations based on publicly available data disclosed in the published annual reports of the Sava RE Group.

The table illustrates that the Sava Group maintains a relatively balanced level of corporate governance across its subsidiaries. Sava Maribor attains the highest index value, reflecting a stable governance structure and consistent performance across all sub-indicators. Regional subsidiaries record slightly lower yet mutually comparable CGI values, ranging between 0.66 and 0.70. Among these subsidiaries, Sava Montenegro registers the highest score, whereas Sava Kosovo exhibits the lowest; this disparity is attributable to the lower level of market development and institutional maturity. The findings confirm that the quality of corporate governance within the group is significantly influenced by local market and regulatory conditions. Conversely, key functions as defined by the Solvency II Directive remain relatively stable across all entities, underpinned by both group-wide standards and overarching regulatory requirements.

Table 5. Comparative CGI Table – Triglav vs. Sava

Group	Insurance company	Governance structure (GOV)	Transparency (DISC)	Shareholder rights (SHR)	ESG	Key functions (KF)	CGI
Triglav	Triglav Ljubljana	0.99	0.99	0.98	0.98	0.99	0.986
Sava	Sava Maribor	0.79	0.79	0.79	0.79	0.79	0.790

Sources: Author's own calculations based on publicly disclosed data from the published annual reports of Sava Re Group member companies.

Table 6. Difference between Groups

Sub-Indicator	Triglav Ljubljana	Sava Maribor	Difference
Governance structure	0.99	0.79	+0.20
Transparency	0.99	0.79	+0.20
Shareholder rights	0.98	0.79	+0.19
ESG	0.98	0.79	+0.19
Key functions	0.99	0.79	+0.20
CGI	0.986	0.790	+0.196

Source: Author's own calculations.

Both insurers operate within a comparable legal and supervisory framework; consequently, the fundamental elements of governance—such as the organisational structure of governing bodies, the operation of key functions, and the protection of stakeholder rights—emanate from the same normative requirements. The disparities in index values do not, therefore, arise from fundamentally distinct governance models, but rather reflect varying degrees of implementation, consistency in disclosure, ESG integration, and the institutional consolidation of governance practices.

Such variations are characteristic of entities operating under the same regulatory regime that nonetheless differ in terms of scale, ownership structure, capital market exposure, and the extent of centralisation of governance functions at the group level. The findings thus suggest that these represent evolutionary differences in the advancement of governance standards, rather than reflecting substantially different concepts or the inherent nature of corporate governance.

Table 7: Market Indicators by Country (2014–2024) and Average CGI

Country	Total gross written premium (EUR)	Premium per capita (EUR)	Penetration (%)	Average CGI of insurance companies
Slovenia	2,428,161,000	1,123.91	4.87	0.86
Croatia	1,436,636,000	355.55	2.51	0.79
Serbia	1,050,000,000	150.00	2.10	0.69
Bosnia and Herzegovina	393,957,700	116.64	2.11	0.71
Montenegro	95,200,650	152.55	1.97	0.70
North Macedonia	210,000,000	100.00	1.85	0.74
Kosovo	107,963,600	58.27	1.13	0.66

Note: All displayed market indicators and CGI values represent averages for the period 2014–2024.

Source: The Croatian Financial Services Supervisory Agency (Hanfa), (<https://www.hanfa.hr/publications/>), National Bank of Serbia (<https://www.nbs.rs/en/finansijske-institucije/osiguranje/poslovanje/>), Slovenian Insurance Association, (<https://www.zav-zdruzenje.si/en/kategorije-publikacij/statistical-publications/>); North

Macedonia Insurance Supervision Agency (ISA) <https://aso.mk/en/category/reports/isa-reports/>; Central Bank of the Republic of Kosovo (<https://bqk-kos.org/stabiliteti-financiar/raporti-i-stabilitetit-financiar/?lang=en>); Insurance Agency of Bosnia and Herzegovina (<https://www.azobih.gov.ba/statistika/default.aspx?id=3867&langTag=en-US>)

All presented market indicators and CGI values represent averages for the period 2014–2024, facilitating a long-term comparison of insurance market maturity and corporate governance quality across countries, independent of short-term cyclical fluctuations.

The results demonstrate a clear correlation between the development of the insurance market and the quality of corporate governance. Slovenia, as the most advanced insurance market, exhibits the highest total gross written premium, the highest premium per capita, and the greatest insurance penetration, while simultaneously attaining the highest average CGI score. This corroborates the premise that a more developed institutional environment, increased market competition, and more stringent regulatory standards exert a positive influence on the quality of corporate governance.

Croatia represents a mid-tier market with average levels of insurance penetration and premium density, which is correspondingly reflected in its intermediate CGI values. A similar trend applies to Serbia, Bosnia and Herzegovina, North Macedonia, and Montenegro, where less advanced developmental indicators are matched by lower CGI scores. Kosovo exhibits the lowest degree of insurance market maturity, which coincides with the lowest recorded value on the Corporate Governance Index.

From a comparative perspective, the table confirms a positive association between insurance market development—measured by penetration and premium per capita—and the quality of corporate governance. This lends support to the hypothesis that the institutional environment and the stage of insurance market development significantly impact the governance standards of insurance companies.

3.1 Research Hypotheses

The central thesis of this paper is that the quality of corporate governance within cross-border insurance groups can be systematically assessed using a newly developed model that incorporates key characteristics of governance structures,

processes, and disclosures. Accordingly, research hypotheses have been formulated, based on an analysis of the relationships between dependent and independent variables across five thematic areas: (1) the composition and operation of management and supervisory bodies; (2) transparency and disclosure; (3) the protection and exercise of shareholder rights; (4) the integration of environmental, social, and governance (ESG) factors; and (5) the performance of key functions in accordance with the requirements of the Solvency II Directive. Each hypothesis takes into account the broader institutional and regulatory framework, enabling the empirical testing of how internal and external factors influence the quality of corporate governance in insurance companies.

The following hypotheses are formulated:

- H1:** The Corporate Governance Index value in insurance companies varies according to the structure and operation of management and supervisory bodies.
- H2:** The Corporate Governance Index value in insurance companies varies according to the scope and quality of disclosures.
- H3:** The Corporate Governance Index value in insurance companies varies according to the level of protection and exercise of shareholder rights.
- H4:** The Corporate Governance Index value in insurance companies varies according to the integration of ESG factors.
- H5:** The Corporate Governance Index value in insurance companies varies according to the positioning and operation of key functions in accordance with Solvency II requirements.
- H6:** The Corporate Governance Index value in insurance companies varies according to the size of the insurance company.
- H7:** The Corporate Governance Index value in insurance companies varies according to the maturity of the insurance market in which the company operates.

In testing these hypotheses, the primary focus is on the direction (positive or negative) and strength of the linear association between the Corporate Governance Index and the individual variables studied. These relationships are first analysed by calculating correlation coefficients. As correlation does not inherently imply

causality, key findings are further verified using multivariate regression models with appropriate control variables.

Particular attention is given to testing hypothesis **H4**, which stems from the assumption that the quality of corporate governance in insurance companies is linked to the integration of ESG factors into their operations. In this context, the research empirically tests whether the CGI value differs significantly based on the ESG indicator level of each insurance company. The analysis is initially based on correlation coefficients and is subsequently expanded to include multivariate regression models, which incorporate control variables such as the size of the undertaking and the level of insurance market development. Such a multi-staged approach facilitates a methodologically more robust assessment of the relationship between corporate governance quality and ESG integration, without making causal inferences.

4 Results

The testing of hypotheses was conducted in two steps: first, by calculating correlation coefficients between the CGI and individual sub-indicators, and second, through multivariate regression models. Since the CGI includes these same sub-indicators, a modified specification was used in the regression analysis. For each hypothesis, a partial index was calculated excluding the sub-indicator under consideration, thereby eliminating the issue of mechanical correlation between variables.

Table 8: Correlation Coefficients between CGI and Sub-Indicators

Variable	Correlation with CGI (r)	Strength of correlation	Statistical significance
Governance structure	0.71	strong positive	$p < 0.01$
Transparency and disclosure	0.82	very strong positive	$p < 0.01$
Shareholder rights	0.69	strong positive	$p < 0.05$
ESG indicator	0.78	strong positive	$p < 0.01$
Key functions (Solvency II)	0.74	strong positive	$p < 0.01$
Insurance company size	0.63	moderate positive	$p < 0.05$
Market development (penetration)	0.66	moderate positive	$p < 0.05$

Source: Author's own calculations.

All analysed sub-indicators demonstrate a positive and statistically significant correlation with the composite CGI, confirming that each constitutes a fundamental determinant of corporate governance quality within insurance undertakings. The strongest correlation is identified in the transparency and disclosure indicator ($r=0.82$), suggesting that the scope and quality of disclosures are among the predominant factors influencing the overall governance assessment. High transparency mitigates information asymmetry, enhances the accountability of management and supervisory bodies, and bolsters stakeholder trust.

A very strong positive correlation is also exhibited by the ESG indicator ($r=0.78$), confirming that the integration of environmental, social, and governance factors is not a peripheral feature but an essential component of a contemporary corporate governance framework. Insurers with higher levels of ESG integration generally exhibit more sophisticated internal control mechanisms, formalised decision-making processes, and greater transparency.

The remaining sub-indicators—governance structure ($r=0.71$), shareholder rights ($r=0.69$), and key functions under Solvency II ($r=0.74$)—likewise show strong positive associations with the CGI. This confirms that traditional governance elements, such as balanced board composition, the effective protection of shareholder rights, and established key functions, remain the bedrock of high-quality governance.

Beyond internal governance factors, insurer size ($r=0.63$) and market development ($r=0.66$) also prove significant. Both variables show a moderate positive correlation with the CGI, suggesting that insurers operating in larger and more developed markets typically achieve higher corporate governance standards. This trend is attributable to more stringent regulatory requirements, greater stakeholder exposure, and heightened pressure for transparent and sustainable operations.

Overall, the correlation analysis confirms that corporate governance quality arises from a synthesis of several interrelated factors, with transparency and ESG integration exerting the most pronounced influence on the aggregate CGI.

Table 9: Correlation and Regression Coefficients for CGI

Dependent variable: CGI or partial CGI (for H1–H5)

Variable	Correlation with CGI (r)	Regression coefficient (β)	Standard error	Statistical significance
Governance structure (GOV)	0.71	0.41	0.06	***
Transparency (DISC)	0.82	0.82	0.09	***
Shareholder rights (SHR)	0.69	0.34	0.15	**
ESG indicator	0.78	0.57	0.07	***
Key functions (KF)	0.74	0.33	0.08	***
Insurance company size (SIZE)	0.63	0.22	0.10	**
Market penetration (PEN)	0.66	0.27	0.10	**

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Panel data: insurance companies in the period 2014–2024.

Source: Author's own calculations.

Correlation coefficients reveal that all variables under consideration exhibit a positive association with the CGI. The most pronounced correlations are observed in transparency and the ESG indicator, underscoring their pivotal role in defining governance quality.

Regression analyses corroborate these findings, maintaining consistency even after the inclusion of control variables. Transparency exerts the most significant impact, followed by ESG integration and governance structure. Among institutional factors, insurer size and market development are statistically significant, suggesting that the quality of corporate governance is dependent not only on internal mechanisms but also on the broader institutional environment.

H1: Structure of Management and Supervisory Bodies

Hypothesis H1: The Corporate Governance Index value in insurance companies varies according to the structure of management and supervisory bodies.

Result: Hypothesis confirmed.

Correlation analysis reveals a positive and statistically significant relationship between the governance structure indicator and the CGI ($r \approx 0.71$). The regression model corroborates the positive influence of this indicator on the CGI, with the coefficient being statistically significant at the 1% level.

Interpretation:

Insurers with a more balanced governance structure, a higher proportion of independent members, and a clear separation of duties achieve higher CGI values. This confirms that the institutional structure of governing bodies constitutes a fundamental element of quality corporate governance.

H2: Transparency and Disclosures

Hypothesis H2: The Corporate Governance Index value varies according to the scope of disclosures.

Result: Hypothesis confirmed.

The transparency indicator exhibits the strongest positive correlation with the CGI ($r \approx 0.82$), and the regression coefficient is statistically significant at the 1% level.

Interpretation:

Insurers with more extensive and higher-quality disclosures, particularly in annual and regulatory reports, achieve higher corporate governance quality. Transparency mitigates information asymmetry and bolsters stakeholder trust, making it a pivotal factor in the composite index.

H3: Shareholder Rights

Hypothesis H3: The Corporate Governance Index value varies according to the level of protection of shareholder rights.

Result: Hypothesis confirmed.

The shareholder rights indicator shows a positive correlation with the CGI ($r \approx 0.69$), and the regression coefficient is statistically significant at the 5% level.

Interpretation:

Insurers providing enhanced protection for minority shareholders, transparent general meeting procedures, and access to information demonstrate higher corporate governance quality. This confirms the importance of shareholder rights as a cornerstone of the governance framework.

H4: ESG Indicator

Hypothesis H4: The Corporate Governance Index value varies according to the integration of ESG factors.

Result: Hypothesis confirmed.

The ESG indicator shows a strong positive correlation with the CGI ($r \approx 0.78$). In the regression model, its influence is statistically significant at the 1% level.

Interpretation:

Insurers with more developed ESG strategies, sustainability disclosures, and the integration of ESG risks achieve higher CGI values. ESG integration thus proves to be a pronounced modern element of quality corporate governance.

H5: Key Functions under Solvency II

Hypothesis H5: The Corporate Governance Index value varies according to the institutional setup of key functions under Solvency II.

Result: Hypothesis confirmed.

The key functions indicator demonstrates a positive correlation with the CGI ($r \approx 0.74$), and the regression coefficient is statistically significant at the 1% level.

Interpretation:

Insurers with clearly organised risk management, compliance, internal audit, and actuarial functions demonstrate higher governance quality. The results validate the significance of the Solvency II regulatory framework.

H6: Insurance Company Size

Hypothesis H6: The Corporate Governance Index value varies according to the size of the insurance company.

Result: Hypothesis confirmed.

The analysis identifies a positive correlation between insurer size (measured by gross written premium) and the CGI.

Interpretation:

Larger insurers operate in more complex regulatory and competitive environments; consequently, they establish more formalised governance structures, more extensive disclosures, and more sophisticated key functions. As a result, they achieve higher corporate governance quality.

H7: Insurance Market Development

Hypothesis H7: The Corporate Governance Index value varies according to the development of the insurance market in which the insurer operates.

Result: Hypothesis confirmed.

Premium per capita and insurance penetration exhibit a positive correlation with the CGI ($r \approx 0.65\text{--}0.68$).

Interpretation:

Insurers operating in more developed markets with higher premium density and penetration achieve higher CGI values. Market development thus represents a significant institutional determinant of corporate governance quality.

5 Discussion

The empirical analysis confirms that all governance pillars included in the CGI exhibit statistically significant relationships with insurance companies' overall governance quality. Transparency and disclosure, together with ESG integration, emerge as the most influential dimensions, indicating that contemporary governance quality in insurance groups increasingly depends on both information availability and the substantive integration of sustainability considerations. Insurer size and market development also display a positive association with CGI values, suggesting that the broader institutional and competitive environment partly shapes governance quality.

At the group level, parent companies consistently achieve higher CGI scores than their subsidiaries. In contrast, observed differences within groups are primarily driven by national regulatory environments and market maturity rather than by fundamentally divergent governance models. These findings underscore the relevance of cross-border institutional factors and confirm the suitability of the CGI for comparative analysis within insurance groups.

At the group level, parent companies consistently achieve higher CGI scores than their subsidiaries, while observed differences within groups are primarily driven by national regulatory environments and market maturity rather than by fundamentally divergent governance models. These findings underscore the relevance of cross-border institutional factors and confirm the suitability of the CGI for comparative analysis within insurance groups.

Among all sub-indicators analysed, transparency and the ESG indicator emerge as the strongest determinants of the CGI, corroborating modern theoretical approaches that treat ESG as an integral part of the governance system. In this context, ESG does not merely represent an additional set of non-financial

disclosures but is increasingly becoming a core element of strategic decision-making, risk management, and the supervisory function.

The results indicate that insurers with a higher level of ESG integration generally exhibit more sophisticated risk management processes, greater transparency, and more formalised governance structures. This supports the hypothesis that ESG acts as a catalyst linking traditional governance mechanisms with the contemporary requirements of sustainable business. In the insurance industry, which is directly exposed to long-term environmental, demographic, and social risks, ESG proves to be a natural extension of the corporate governance system.

Hypothesis H4 stems from the assumption that the quality of corporate governance in insurance companies is closely linked to the integration of ESG factors into their business. The empirical results confirm this assumption, as the ESG indicator shows a strong and statistically significant positive correlation with the CGI. This implies that insurers that systematically incorporate environmental, social, and governance aspects into their strategic documents, decision-making processes, and internal control systems generally achieve a higher level of overall governance quality.

In this context, ESG is seen not merely as an additional set of disclosures but as an integrated element of strategic decision-making, risk management, and the supervisory function, unifying environmental, social, and governance aspects into a single governance framework. Insurers with a higher level of ESG integration generally demonstrate more advanced oversight processes, greater transparency, and more balanced board structures, which is directly reflected in higher CGI values.

Regression analysis results further corroborate that ESG integration is a significant determinant of governance quality, even after accounting for control variables such as insurer size and market development. The positive and statistically significant regression coefficient indicates that ESG exerts an independent influence on the CGI value, irrespective of the institutional operating conditions.

Traditional governance components—including the structure of management and supervisory bodies, shareholder rights, and the organisational positioning of key functions under Solvency II—continue to exert a significant influence. The findings corroborate that insurers characterised by balanced board compositions, a higher

proportion of independent directors, and a clear segregation of duties typically achieve superior scores on the composite index. However, when viewed in conjunction with the ESG indicator, it becomes evident that traditional governance mechanisms per se are no longer a sufficient condition for achieving high-quality corporate governance.

The analysis of insurance company size and market development further underscores that the quality of corporate governance is not merely a product of internal organisational characteristics but is also shaped by the institutional environment. Larger insurers operating in more advanced markets—characterised by higher levels of insurance penetration and premium density—consistently record higher CGI values. This correlation is attributable to more stringent regulatory requirements and heightened stakeholder pressure regarding sustainable business practices.

The comparative analysis of Slovenian insurers indicates a relatively high overall standard of corporate governance, reflecting a stable regulatory landscape and a long-standing institutional tradition. The disparity between the two benchmark insurers, Triglav Ljubljana and Sava Maribor, amounts to approximately 0.20 index points, representing a moderate variance in governance quality. Whilst both entities are positioned within the top tier of the analysed companies, the difference primarily reflects Triglav's superior levels of transparency and its more advanced ESG strategy. Both groups exhibit a similar pattern amongst their subsidiaries, which generally record slightly lower index values, driven by disparities in their respective institutional environments. Within both groups, Solvency II key functions emerge as the most stable sub-indicator, confirming the pervasive impact of the unified regulatory framework. Moreover, regression analysis indicates that transparency and ESG integration exert a comparable and statistically significant influence on corporate governance quality across both groups. The results thus confirm that the underlying governance patterns and determinants of quality do not differ fundamentally between the two cross-border insurance groups; instead, observed disparities arise primarily from the degree of institutional integration and the level of market development.

6 Conclusions

The objective of this research was to develop a model for measuring corporate governance quality in cross-border insurance groups and to empirically examine the influence of selected governance, ESG, and institutional factors on the Corporate Governance Index (CGI) value. Based on theoretical foundations and the regulatory framework, the CGI was designed as a composite index comprising five thematic sub-indicators: the structure of management and supervisory bodies, transparency and disclosures, shareholder rights, ESG factors, and key functions under Solvency II.

The empirical analysis of panel data for the period 2014–2024 confirmed all of the research hypotheses. The results indicate that all of the analysed sub-indicators exert a statistically significant and positive influence on the overall CGI value. Notably, transparency and the ESG indicator emerge as the most prominent determinants, confirming their central role in contemporary corporate governance models.

A specific contribution of this research is the confirmation that ESG is not merely an additional or secondary governance element, but rather one of the key factors shaping the quality of corporate governance in insurance companies. Insurers with higher levels of ESG integration generally exhibit more advanced risk management systems, greater transparency, and more formalised governance structures. In this regard, ESG acts as a catalyst, linking traditional governance mechanisms with the contemporary requirements of sustainable business practices.

The study further confirms that corporate governance quality is contingent not only on internal governance structures but also on the institutional environment. Larger insurers and those operating in more advanced markets typically achieve higher index values, which is associated with more stringent regulatory requirements and heightened stakeholder pressure regarding sustainability.

A comparative analysis of insurers in Slovenia and within the two largest insurance groups in the region shows that disparities in governance quality primarily stem from differences in market development, transparency levels, and ESG integration. Despite these variations, the majority of the analysed insurers achieve relatively high

index values, indicating a generally well-developed governance environment in the region.

The main contribution of this research lies in the development of a methodological model for measuring corporate governance quality, enabling comparisons across insurers, countries, and groups while incorporating modern elements such as ESG factors and Solvency II key functions. Such a model is valuable for both regulators and insurance governing bodies, as it facilitates the systematic monitoring and improvement of governance practices and the better integration of sustainability factors into business strategies.

The research results confirm that the CGI represents a useful and methodologically sound tool for assessing governance quality in cross-border insurance groups. The model provides a comparable, structured, and empirically verifiable assessment of key governance areas while simultaneously integrating modern elements of sustainable business. The particular value of the index lies in its ability to bridge traditional governance mechanisms with ESG factors, which increasingly shape strategic decisions, risk management, and stakeholder relations. The findings suggest that ESG factors are no longer merely a supplementary element of non-financial disclosure but represent a core pillar of modern corporate governance in the insurance industry. Insurers with higher ESG integration generally demonstrate more sophisticated governance processes, higher transparency, and a more systematic inclusion of long-term risks in business decisions. ESG thus functions as a unifying framework, integrating environmental, social, and governance aspects into a single system of responsible and sustainability-oriented management.

Therefore, the CGI serves as a practical analytical tool for cross-country and intra-group comparisons, while providing a basis for the further development of governance standards, regulatory approaches, and sustainability strategies in the insurance sector. In this context, ESG factors are becoming a central element of future corporate governance development, linking financial performance, risk management, and long-term value creation.

The significance of these findings stems primarily from the fact that the CGI is designed exclusively using publicly available data, ensuring the transparency, reproducibility, and practical utility of the model. This approach allows for an

objective and comparable assessment of corporate governance quality without requiring access to internal or confidential sources. The results confirm that the key determinants of the CGI are transparency and ESG integration, demonstrating that ESG is no longer just an additional disclosure but is becoming a cornerstone of the modern corporate governance system. The model thus represents a valuable tool for regulators, investors, and management bodies, enabling a systematic and empirically grounded assessment of governance quality in cross-border insurance groups.

Future research could further disaggregate the ESG pillar to more clearly distinguish between companies that treat ESG primarily as a reporting or compliance requirement and those in which ESG aspects are genuinely embedded in corporate governance structures, strategic decision-making, and risk management processes. In addition, it would be meaningful to extend the application of the proposed Corporate Governance Index to non-European insurance markets or to regulatory frameworks different from Solvency II, thereby testing the robustness and adaptability of the model across diverse institutional environments. From a methodological perspective, future studies could move beyond correlation analysis and employ more advanced panel-data techniques to explore potential causal relationships between corporate governance quality, ESG integration, and the financial or prudential performance of insurance undertakings. Finally, the CGI could be further developed as a practical supervisory tool for benchmarking or early warning purposes, enabling regulators to monitor more systematically the quality and consistency of corporate governance within cross-border insurance groups.

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URBAN GOVERNANCE AS A FOUNDATION OF SUSTAINABLE TOURISM DEVELOPMENT: THE CASE OF WIENER NEUSTADT

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This paper analyses sustainability-driven digital transformation in medium-sized European cities through a case study of Wiener Neustadt, applying the SMART TOUR (Interreg Europe) framework. Based on a structured review of sustainable tourism, smart cities, and destination governance literature, digital transformation is conceptualised as a governance-led strategic process rather than a purely technological shift. The study employs qualitative policy and strategic document analysis, focusing on the STEP WN 2030 urban development strategy and the Klimaneutral 2040 climate strategy. It examines how these frameworks integrate digitalisation, sustainability, and tourism objectives, and how digital tools support resource efficiency, performance monitoring, and stakeholder engagement. The paper contributes to the discussion on smart tourism and sustainable urban development by suggesting how smart tourism models may be applied beyond mass tourism contexts and highlighting secondary cities as key arenas for sustainability-oriented digital transformation, offering context-specific insights with potential relevance for policymakers.

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1 Introduction

In the 21st century, tourism faces new challenges and opportunities shaped by rapid technological change and growing demand for sustainability. The rise of smart destinations reflects not only innovation, but also the need for cities to coordinate environmental responsibility, digital infrastructure, and visitor experience within coherent policy frameworks. The key question is therefore not whether cities adopt digital tools, but how these tools are embedded in governance structures that ensure long-term sustainability.

Digital transformation in tourism cannot be understood solely as a technological upgrade or marketing instrument. Rather, it represents a governance challenge requiring alignment between urban development, climate policy, economic positioning, and destination management. Particularly in medium-sized cities, where institutional capacities differ from metropolitan areas, the effectiveness of smart tourism initiatives often depends on cross-sectoral coordination, data-driven decision-making, and integrated planning.

Wiener Neustadt provides a relevant case for examining this governance dimension. With its industrial and historical heritage, the city positions itself as a regional technological and educational hub while also developing as an emerging tourism destination. Its urban development strategy (STEP WN 2030+) and climate roadmap (Klimaneutral 2040) treat digitalisation and sustainability as interconnected components of long-term urban governance.

Despite growing literature on smart tourism, sustainable destinations, and smart cities, several research gaps remain. First, studies mainly focus on large metropolitan areas or internationally recognised destinations, while medium-sized and secondary cities remain underexplored. Second, although governance is often acknowledged, fewer studies examine how tourism development is shaped through the institutional capacities of secondary cities. Third, limited attention has been devoted to how urban development strategies and climate roadmaps jointly influence tourism attractiveness and local development.

The aim of this study is to explore, through the strategic documents of Wiener Neustadt, how a medium-sized city can strengthen its attractiveness as a sustainable tourism destination through governance-led digital transformation while maintaining livability and social cohesion. The research examines how digital infrastructure, monitoring systems, and cross-sectoral coordination contribute to sustainability outcomes and create opportunities for tourism management. The study argues that in secondary cities digital transformation in tourism emerges primarily as a function of institutional capacity and policy coherence rather than as a purely technology-driven process.

2 Sustainability in Tourism: Concepts, Challenges and Development Approaches

The concept of sustainability is most widely associated with the Brundtland Commission, which defined it as development that meets present needs without compromising future generations (Brundtland, 1987). This definition highlights intergenerational responsibility and remains a foundational reference in sustainability research.

In tourism, the World Tourism Organization defines sustainable tourism as development that satisfies the needs of visitors and host regions while preserving future opportunities, balancing economic, social, cultural, and environmental considerations (WTO, 1998).

Sustainability is best understood as a systems-oriented approach integrating environmental, social, and economic dimensions. Rather than treating these domains separately, it emphasizes their interdependence and the need for coordinated governance. Ostrom's framework reinforces this perspective by highlighting multi-level governance, stakeholder interdependence, and context-sensitive resource management. Related concepts—such as environmental justice, community economic development, and ecolocalism—stress long-term resilience and local responsibility.

In urban contexts, sustainable tourism intersects with paradigms such as the green city, eco-city, low-carbon city, and smart city, linking environmental responsibility with governance and technological innovation (Kanuri, 2016).

Although sustainability appears as a contemporary concept, earlier societies often relied on resource-use practices that maintained ecological balance. Modern industrial systems, however, are characterized by high consumption, linear production patterns, and intensive resource extraction.

Despite increasing environmental awareness—such as energy efficiency, recycling, and low-emission mobility—these measures have not fully offset structural pressures. Since the early 1970s, humanity’s ecological footprint has exceeded the Earth’s regenerative capacity. The Ecological Footprint indicator developed by Wackernagel and Rees (1996) demonstrates the gap between available natural capital and actual consumption, underlining the need for systemic integration of sustainability into long-term strategies.

Tourism has expanded significantly due to globalization, economic growth, and technological development. According to UNWTO (2023), tourism is sustainable when it accounts for its present and future economic, social, and environmental impacts while meeting the needs of visitors, host communities, and service providers.

Sustainable tourism aims to generate long-term economic benefits—such as employment and income stability—while preserving cultural heritage, strengthening local identity, and protecting ecological systems. Its central objective is to balance visitor experience quality with environmental and social responsibility. In this context, resource productivity links economic performance with environmental efficiency.

3 The Scientific Approaches to Sustainable Tourism Development

Research distinguishes four dominant models of sustainable tourism development (Buckley, 2012):

A) Product-Driven Approach

Economic objectives dominate, and environmental considerations are secondary. This model is typical in destinations heavily dependent on tourism revenues (Szabó, 2016).

B) Environment-Driven Approach

Environmental protection is central to tourism planning. Economic development is aligned with ecological sustainability, reflecting a strong long-term orientation (Szabó, 2016).

C) Coercive Approach

Tourism growth is prioritized to compensate for economic decline, often neglecting environmental concerns (Szabó, 2016).

D) Neotenous Approach

Tourism expansion is deliberately limited to preserve environmental quality. Infrastructure development is restricted, representing a high level of sustainability (Macbeth, 2005).

In practice, an environment-driven model often provides a balanced pathway, integrating economic and ecological considerations within destination governance (Szabó, 2016).

4 Key Elements and Structure of Smart Governance

Information and communication technologies (ICTs) underpin modern public administration and support the development of e-government and smart governance systems (Estevez and Janowski, 2013). Smart governance refers to integrated, data-driven, and participatory forms of administration supported by technologies such as AI, data analytics, blockchain, and IoT.

These technologies enhance decision-making quality, service delivery, and administrative efficiency (Jiang, 2021; Kim et al., 2022). Smart governance also emphasizes responsiveness to citizen expectations and operational effectiveness (MacLean and Titah, 2022; Charalabidis and Koussouris, 2012).

Beyond technological integration, smart governance incorporates ethical and legal principles such as transparency, accountability, and inclusivity (Tay et al., 2018). ICT-supported policymaking can strengthen citizen participation and institutional responsiveness (Scholl and AlAwadhi, 2016).

However, challenges include data security, privacy risks, digital inequality, cybersecurity threats, and high implementation costs (Pansera et al., 2022; Przybilowicz et al., 2022; Popova and Popovs, 2023). Overreliance on complex technologies may reduce accessibility, underscoring the need to balance digital tools with participatory governance mechanisms.

Before presenting the analytical model, it is useful to summarise the main components of smart governance discussed in previous literature. Figure 1 illustrates the institutional and technological dimensions that support governance-oriented urban transformation.

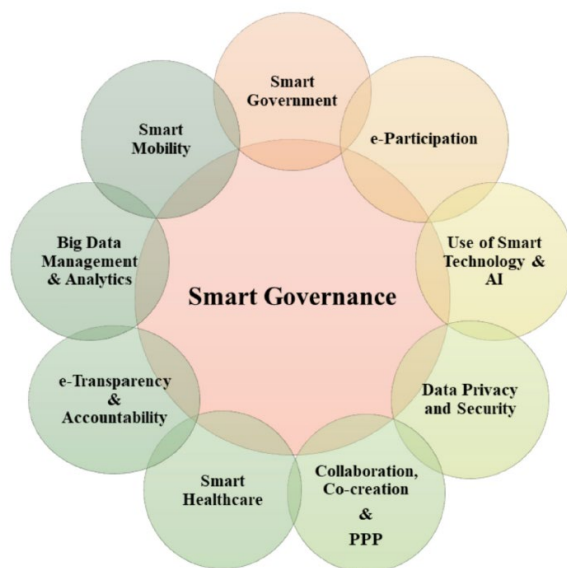


Figure 1: Components of smart governance

Source: (Abdullah Kaiser, 2024)

4.1 Conceptual Model of Smart Governance

The smart governance model applied in this study was developed by Abdullah Kaiser (2024), building on the work of Bolívar and Meijer (2016), Mergel et al. (2019), and Meijer and Bolívar (2016). Inputs refer to policy adjustments, legislative reforms, and resource allocation. Outputs represent tangible achievements, such as open data practices, ICT implementation, collaborative mechanisms, and citizen engagement initiatives. Outcomes capture broader impacts, including improved public services, administrative performance, institutional coordination, and policy effectiveness. This structure enables the assessment of governance preparedness, implementation dynamics, and relational consequences.

5 Green Branding as a Competitive Advantage

Branding principles extend beyond products to organizations, individuals, and places (Papp-Váry, 2007; 2009; Anholt, 2007). In recent years, sustainability has become a defining element of city branding strategies.

Urban communication addresses both tourists and residents, as both shape long-term competitiveness (Piskóti & Papp-Váry, 2018). Integrating sustainability into branding enhances reputation and strengthens regional positioning (Lukács et al., 2022).

The POE model distinguishes paid, owned, and earned media (Papp-Váry & Farkas, 2018). In urban branding, earned media—especially user-generated content—has gained credibility, while owned media channels remain central for communicating sustainability (Papp-Váry, 2018; Papp-Váry & Szűcs-Kis, 2021).

Research shows that sustainability-oriented branding enhances attractiveness and perceived livability (Garanti et al., 2024; Rehan, 2014). Targeting younger generations is particularly important, as sustainability is a core value for Generation Z (Papp-Váry et al., 2023).

6 Definitions and Pillars of the Smart City

The smart city concept emerged in response to urbanization and governance challenges. While initially focused on ICT infrastructure, it increasingly encompasses integrated urban management (Árvai, 2022).

Hall (2000) emphasizes intelligent integration of transport, utilities, and communication systems. Harrison et al. (2010) define the smart city as collective intelligence emerging from interconnected physical, digital, and social systems. Dobos (2015) highlight coordinated urban functions supported by innovative organizational methods and technology.

At EU level, smart city initiatives prioritize energy efficiency, resource management, and emission reduction (Dobos, 2015). Giffinger et al. (2007) identify six pillars: Smart Governance, Smart Economy, Smart Environment, Smart People, Smart Living, and Smart Mobility. Effective smart cities integrate these dimensions to enhance quality of life and operational efficiency.

7 Technological Transformation of Tourism Destinations

Tourism destinations can be understood as market-oriented systems where tourists and providers co-create experiences (Reinhold et al., 2015). Contemporary destinations rely increasingly on ICT, IoT, smartphones, and data-driven solutions (Xiang et al., 2015).

Smart destinations integrate advanced technological infrastructure to enhance sustainability, resident well-being, and visitor experiences. They enable personalized services and real-time information exchange.

User-generated content (UGC) plays a key role in smart tourism. Big Data analytics allow destinations to incorporate visitor feedback into experience design and service improvement (Marine-Roig and Anton Clavé, 2015).

8 Methodology

8.1 Research Design

This study applies a qualitative research design based on strategic document analysis to examine how sustainability-driven digital transformation is embedded in the governance frameworks of a medium-sized European city. The research adopts an interpretive policy-analysis approach, focusing on how digitalisation, sustainability, inclusivity, culture, and integrated planning are conceptualised, operationalised, and institutionally anchored in formal strategic documents.

Wiener Neustadt represents a theoretically relevant case because it is a medium-sized European city with formally adopted urban development and climate strategies, while simultaneously positioning itself as an emerging destination. The selection was further supported by strong contextual accessibility, enabling more nuanced interpretation of local governance and development processes.

The case study method was selected as an appropriate design due to the exploratory nature of the research and the aim of generating transferable insights from a secondary city context. Wiener Neustadt represents a theoretically relevant case, as it combines (1) a comprehensive urban development strategy and (2) a dedicated climate-neutrality roadmap, both formally adopted and legally anchored at municipal level.

The empirical material consists of two core strategic documents:

- STEP WN 2030+ – Stadtentwicklungsplan Wiener Neustadt
- Wiener Neustadt Klimaneutral 2040 – Klimafahrplan

Together, these documents provide a structural (urban planning) and operational (climate implementation) perspective on the city's sustainability-oriented transformation.

8.2 Analytical Framework

The analysis is guided by a conceptual framework derived from smart tourism and sustainable urban governance literature, complemented by the European smart tourism policy discourse.

Smart Tour is a European collaboration helping destinations deliver travel that is seamless, sustainable and welcoming. Under the title Smart Tourism–Smart Destinations: Accessibility, Sustainability, Digitalisation, Cultural Heritage & Creativity, the project supports cities and regions to develop practical policies and tools that connect these themes. The aim is to align visitor services with community needs, using clear data and shared governance (a shared dashboard and quarterly forum) to guide decisions. Partners learn from each other, test solutions, and turn plans into steady improvements that last.

Smart Tour responds to rapidly changing traveller needs through five core pillars, which were defined a priori as the study's analytical dimensions:

1. Digital empowerment – user-friendly digital tools, services, infrastructure, real-time information systems, and managerial analytics.
2. Accessibility for all – inclusive design, barrier reduction, training, and equal access for diverse social groups.
3. Sustainability – low-impact mobility, resource efficiency, climate mitigation and adaptation, and protection of natural and cultural assets.
4. Culture & creativity – support for local creative industries, cultural heritage preservation, and authentic place-based narratives.
5. Holistic planning – cross-sectoral integration of technology, innovation, governance, and inclusivity across the full visitor and resident journey.

These dimensions function as structured coding categories and allow systematic comparison between the two strategies.

8.3 Data Collection

The study relies exclusively on officially published municipal strategic documents. Both documents are publicly accessible and legally adopted policy instruments.

- The STEP WN 2030+ functions as the city's statutory urban development concept under the Lower Austrian spatial planning framework.
- The Klimaneutral 2040 roadmap represents the city's climate neutrality strategy aligned with national and EU climate targets.

No interviews or primary survey data were collected for this phase of the research, as the objective was to examine formal governance intentions and institutionalised planning narratives.

8.4 Analytical Procedure

The document analysis followed a four-step procedure:

Step 1: Structural reading

Both documents were first examined to identify their institutional status, planning horizon, legal embeddedness, and governance structure.

Step 2: Thematic coding

Using the five predefined analytical dimensions, relevant passages were coded manually. Coding focused on:

- Explicit policy objectives
- Stated measures and action plans
- Monitoring and evaluation mechanisms
- Governance and stakeholder engagement structures

Step 3: Cross-document comparison

The structural urban development strategy (STEP WN 2030+) and the operational climate roadmap (Klimaneutral 2040) were compared to identify complementarities, overlaps, and functional differentiation between strategic vision and implementation instruments.

Step 4: Interpretive synthesis

Findings were synthesised to assess the degree to which Wiener Neustadt's strategies reflect a governance-led model of digital and sustainability transformation rather than a purely technological or marketing-driven smart city approach.

The main strength of strategic document analysis lies in its ability to systematically identify formal policy priorities, institutional commitments, and overarching governance narratives. Because the analysed documents are legally adopted and embedded in official planning frameworks, they represent formal development directions rather than informal or speculative visions.

At the same time, certain limitations must be considered. The analysis examines planned strategies rather than their actual implementation outcomes. It does not include stakeholder interviews, and therefore does not capture individual perceptions, informal practices, or everyday operational realities. In addition, tourism-related measures are not always explicitly identified as such in urban strategy documents, which requires careful interpretation to connect broader policy objectives with their tourism-related implications.

Despite these constraints, the methodological approach provides conceptual clarity and allows for analytical comparability. For this reason, it is particularly well suited to conference presentations and academic journal publications focusing on governance, policy design, and strategic planning.

By combining structured policy document analysis with a smart tourism-oriented analytical framework, the study aims to contribute methodologically to the literature in two ways. First, it broadens the scope of smart tourism research beyond its traditional focus on destination marketing and ICT adoption, shifting attention toward governance-embedded digital transformation processes. Second, it seeks to explore how secondary cities can be systematically examined through their integrated urban development and climate strategies in order to assess their readiness for sustainability-oriented tourism development.

9 STEP WN 2030+ – Urban Development Strategy

9.1 Digital Empowerment

The STEP WN 2030+ Urban Development Strategy explicitly identifies digitalisation as a structural global trend shaping contemporary urban development (Section A.1).

In this context, digital transformation is not treated merely as a technological upgrade but as a governance-related shift toward data-driven and knowledge-based decision-making.

Urban development is interpreted as an integrated process supported by digital infrastructure and analytical tools. The strategy promotes the development of intelligent mobility systems and digitally supported transport planning. This may provide a basis for more efficient coordination of urban flows. Although tourism-specific digital tools are not explicitly detailed, these structural interventions may create the conditions for future real-time information systems and integrated service platforms. Furthermore, the document emphasises the role of integrated urban planning databases, including land-use mapping and environmental monitoring systems.

The document refers to planning databases and monitoring systems. This may strengthen evidence-based planning capacity and allow continuous evaluation of spatial and environmental developments. Transparency is also a key element: planning materials and strategic documents are publicly accessible online, reinforcing participatory governance and open access to information.

Overall, digital empowerment in the STEP WN 2030+ strategy appears primarily at the infrastructural and governance levels rather than as direct tourism service innovation. The document establishes the institutional and digital foundations necessary for a knowledge-driven and potentially smart destination-oriented urban development model.

9.2 Accessibility for All

The STEP WN 2030+ Urban Development Strategy emphasises the importance of social infrastructure, intergenerational balance, and a liveable residential environment (Section B.6). Accessibility is framed as a core principle of inclusive urban development, aiming to ensure that the city remains functional and supportive for residents of all ages and social groups.

A central element of this approach is the promotion of barrier-free public spaces and accessible transport systems. By reducing physical obstacles and improving mobility conditions, the strategy addresses the needs of people with disabilities, older adults, families with children, and other vulnerable groups. In addition, the encouragement of a denser, mixed-use urban structure enhances everyday accessibility by bringing housing, services, and workplaces closer together, thereby reducing car dependency and strengthening local cohesion.

The preservation and development of green and open spaces further contribute to inclusive urban quality. Public parks and recreational areas are treated as essential shared assets accessible to all residents, supporting both well-being and social interaction. Accessibility is therefore understood not only in physical terms but also in relation to equal access to urban amenities.

Importantly, the participatory planning process—through public consultations and citizen involvement—reflects an inclusive governance philosophy.

Overall, accessibility and inclusivity in the STEP WN 2030+ are interpreted within the full urban life cycle, extending beyond tourism considerations and positioning equitable access as a structural objective of long-term city development.

9.3 Sustainability

Sustainability constitutes a central and integrative principle within the STEP WN 2030+ Urban Development Strategy. The document addresses both climate mitigation and climate adaptation in a coordinated manner (Section A.5), positioning environmental responsibility as a fundamental task of long-term urban governance rather than as a separate policy domain.

A key priority is the controlled management of settlement development in order to limit urban sprawl. By guiding spatial growth and promoting more compact urban structures, the strategy seeks to reduce land consumption, protect surrounding natural areas, and optimise infrastructure efficiency. This spatial approach directly supports climate objectives by minimising transport demand and preserving ecological balance.

Environmentally friendly mobility is another major pillar of the sustainability framework. The promotion of sustainable transport solutions aims to decrease greenhouse gas emissions while improving urban quality of life. In parallel, the protection and expansion of green spaces are emphasised as essential elements of climate adaptation, helping to mitigate heat island effects and enhance urban resilience. Energy-efficient spatial use and planning further contribute to reducing environmental impacts at the systemic level.

Overall, sustainability in the STEP WN 2030+ is not treated as a thematic add-on but as a horizontal guiding principle that permeates the entire strategic framework. Climate protection, resource efficiency, and environmental resilience are embedded across planning objectives and measures, shaping the long-term development trajectory of the city.

9.4 Culture and Creativity

The STEP WN 2030+ Urban Development Strategy positions Wiener Neustadt as an economic, educational, and cultural centre within its regional context. Culture is not treated as an isolated sector but as an integral component of urban identity and long-term competitiveness. In this sense, cultural assets and creative potential are embedded within broader spatial and development objectives.

A central element of this orientation is the concept of a “Lebendige Innenstadt” (vibrant city centre), which aims to strengthen the multifunctional character of the historic core. The strategy promotes the integration of residential, commercial, cultural, and social functions in order to maintain urban vitality. This approach supports everyday use by residents while simultaneously enhancing the experiential quality of the city for visitors.

The integration of historical heritage into urban development planning further reinforces the cultural dimension. Built heritage and historically significant urban structures are regarded as valuable resources that contribute to place identity and spatial continuity. In addition, the revitalisation of community spaces and public areas fosters social interaction and cultural expression, strengthening the city's role as a living cultural environment rather than a static heritage site.

Creative industries appear more indirectly within the economic development sections of the strategy, where innovation, knowledge-based activities, and research institutions are emphasised.

Overall, cultural heritage and a vibrant urban core provide a strong foundation for tourism narratives; however, the document adopts primarily a spatial and structural perspective rather than a marketing-oriented approach. Culture is framed as a driver of urban quality and identity, with tourism emerging as a potential, but not exclusive, outcome.

9.5 Holistic Planning

The STEP WN 2030+ Urban Development Strategy explicitly defines itself as an integrative planning concept (Section A.4). Rather than addressing urban challenges in isolated policy segments, the document establishes a comprehensive framework that connects spatial development, environmental protection, mobility, social infrastructure, and economic competitiveness within a unified strategic vision.

One of the core instruments supporting this holistic approach is the inclusion of a Strategic Environmental Assessment (SUP), which evaluates the environmental implications of planned measures. This mechanism ensures that sustainability considerations are systematically integrated into decision-making processes. By embedding environmental evaluation into the planning cycle, the strategy strengthens coherence between long-term objectives and operational actions.

Holistic planning is further reinforced through multi-actor governance structures. The development of the strategy involved political representatives, experts, administrative units, and citizens, reflecting a collaborative and participatory planning model. Such an approach enhances policy legitimacy and facilitates cross-sectoral coordination among stakeholders responsible for implementation.

Importantly, the STEP WN 2030+ is not merely a visionary document but a legally binding municipal regulation adopted under spatial planning law. This formal status strengthens its integrative capacity by aligning diverse policy domains under a single regulatory framework. Overall, the strategy provides a strongly holistic, cross-sectoral development model that connects governance, sustainability, and spatial planning within a coherent long-term urban trajectory.

9.6 Integrated Summary of Analytical Findings

The STEP WN 2030+ Urban Development Strategy presents a coherent and structurally integrated approach to long-term urban development. Across the dimensions of digital empowerment, accessibility, sustainability, culture and creativity, and holistic planning, the document consistently treats urban transformation as a governance-driven and cross-sectoral process. Rather than focusing on isolated projects, the strategy establishes a comprehensive framework that connects spatial planning, environmental responsibility, mobility, and social inclusion. From a scholarly perspective, this reflects a mature understanding of sustainability-oriented urban governance. At the same time, certain strategic and operational limitations become visible.

Digital empowerment is primarily interpreted as strengthening administrative capacity and improving evidence-based planning. The emphasis on data systems, intelligent mobility, environmental monitoring, and transparency indicates a shift toward more analytical and knowledge-based decision-making. However, digitalisation remains largely internal and infrastructural. The strategy does not clearly articulate how digital tools could enhance user experience, visitor management, or destination competitiveness. In this sense, digital transformation is embedded in governance structures but is not yet fully mobilised as a strategic driver of innovation or external positioning.

The accessibility and sustainability dimensions are strongly embedded within the overall framework. Accessibility is understood broadly, including spatial proximity, mixed-use urban form, green space availability, and participatory governance. Sustainability functions as a horizontal principle shaping land use, mobility policy, and climate adaptation. This integrated approach can strengthen the long-term resilience of the city. Nevertheless, the strategy remains largely normative in tone.

While objectives are clearly formulated, there is limited emphasis on measurable indicators, benchmarking, or concrete evaluation mechanisms. From an academic standpoint, stronger alignment between strategic goals and performance measurement would enhance analytical clarity and implementation transparency.

Culture and creativity are positioned as elements of urban identity and quality of life rather than as explicitly market-oriented tools. The focus on a vibrant city centre and heritage integration supports place-based development and reinforces local cohesion. Tourism is treated as a possible outcome of spatial and cultural vitality rather than as a central strategic objective. This resident-centred approach enhances sustainability but may limit the city's ability to compete actively within regional tourism markets. Overall, STEP WN 2030+ can be interpreted as a promising governance template for sustainability-driven development in a secondary city context. Its main strengths lie in institutional integration and climate mainstreaming, while its main challenges relate to operationalisation, measurable outcomes, and clearer strategic positioning in digital and tourism-related innovation.

10 Wiener Neustadt Climate Neutral 2040 - Climate Roadmap of the Climate Pioneer City of Wiener Neustadt

10.1 Digital Empowerment

The Wiener Neustadt Klimaneutral 2040 strategy adopts a data-driven approach to climate governance, positioning digitalisation primarily as a tool for monitoring and management. The strategy is built upon a greenhouse gas inventory prepared according to the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC), using 2022 as the baseline year. This methodological foundation signals a commitment to internationally recognised standards and enhances the comparability and credibility of local climate policy.

A central component of the strategy is the establishment of a structured monitoring and evaluation system. The document outlines mechanisms for tracking emissions, assessing progress, and adjusting measures over time. The development of an emissions database enables systematic data collection and continuous performance assessment. In this sense, digital empowerment is operationalised through analytical capacity rather than through service-oriented digital innovation.

Stakeholder governance is also supported by data transparency and workshop-based consultation processes. More than 30 stakeholders were involved in the development and prioritisation of measures, reflecting a collaborative governance model grounded in shared information and evidence-based dialogue. Digital tools thus facilitate coordination, accountability, and adaptive policy learning.

Overall, in the Klimaneutral 2040 strategy, digitalisation serves primarily managerial and monitoring functions. Rather than focusing on user-facing technological solutions, the strategy strengthens institutional capacity for data-driven climate governance. This approach reinforces administrative effectiveness and long-term accountability, positioning digital empowerment as an enabling mechanism for structured and measurable climate transition.

10.2 Accessibility for All

The Wiener Neustadt Klimaneutral 2040 strategy distinguishes clearly between ecological, social, and economic dimensions of sustainability. Within this tripartite framework, accessibility is primarily embedded in the social dimension, where the climate transition is framed not only as an environmental necessity but also as a societal transformation that must remain equitable and inclusive.

A central principle in this regard is the concept of a “just transition.” The strategy acknowledges that climate mitigation measures may generate unequal burdens across social groups and therefore emphasises the need to ensure fairness in implementation. This perspective extends accessibility beyond physical infrastructure, addressing distributional effects and social resilience within the energy and mobility transition.

Citizen involvement also plays a significant role in reinforcing inclusivity. The development and prioritisation of measures involved stakeholder workshops and participatory processes, allowing diverse actors to contribute to climate planning. Such engagement mechanisms enhance procedural accessibility by integrating community perspectives into decision-making.

Inclusivity further emerges indirectly through the expansion of sustainable mobility alternatives and energy transition measures. By promoting environmentally friendly transport options and supporting systemic energy transformation, the strategy aims to provide accessible low-carbon choices for residents. Overall, accessibility in the Klimaneutral 2040 strategy is not addressed as a standalone spatial issue but is embedded within broader social justice and transition governance considerations.

10.3 Sustainability

Sustainability constitutes the central axis of the Wiener Neustadt Klimaneutral 2040 strategy. Unlike broader urban development frameworks, this document focuses explicitly on achieving climate neutrality by 2040 and translates sustainability objectives into concrete operational measures. The strategy moves beyond normative commitments and defines a structured pathway for emission reduction and systemic transformation.

A key feature of the document is the development of a comprehensive action plan comprising more than 200 measures. These measures are organised across major policy domains, including mobility, stationary energy, waste management, and governance. This sectoral structure ensures that sustainability is addressed as a multi-dimensional challenge requiring coordinated intervention across urban systems rather than isolated environmental projects.

Specific actions include the expansion of photovoltaic (PV) capacity, the electrification of the municipal vehicle fleet, and the promotion of low-emission mobility alternatives. These measures indicate a strong focus on energy transition and transport decarbonisation as primary levers for reducing greenhouse gas emissions. Waste reduction and resource efficiency initiatives further complement the mitigation agenda, reinforcing circular economy principles.

Importantly, sustainability is embedded within a structured monitoring framework that enables ongoing evaluation of progress. Through measurable targets and continuous performance assessment, the strategy operationalises sustainability at an implementation level. In this sense, climate neutrality is not presented as a symbolic ambition but as a measurable and institutionally managed transformation process.

10.4 Culture and Creativity

In contrast to the urban development strategy, the Wiener Neustadt Klimaneutral 2040 roadmap places less explicit emphasis on cultural and creative dimensions. Its primary focus lies on climate mitigation, energy transition, and systemic decarbonisation. Culture is not addressed as a standalone policy field within the climate framework.

However, elements of cultural sustainability appear implicitly through the strategy's commitment to improving urban quality of life and strengthening social cohesion. Measures aimed at enhancing public spaces, promoting sustainable mobility, and reducing environmental stress contribute indirectly to the preservation of liveable and socially vibrant urban environments. These conditions are fundamental for maintaining local identity and everyday cultural practices.

The emphasis on participatory governance and stakeholder engagement also supports cultural sustainability in procedural terms. By involving diverse actors in workshops and decision-making processes, the strategy fosters collective ownership of the climate transition. Such inclusive processes can strengthen community bonds and shared urban narratives, which are core components of cultural resilience.

Overall, while culture and creativity are not foregrounded in the Klimaneutral 2040 strategy, the enhancement of urban well-being, community interaction, and social stability indirectly reinforces the cultural foundations of the city. In this sense, cultural sustainability emerges as a supportive outcome of environmental transformation rather than as a direct policy objective.

10.5 Holistic Planning

The Wiener Neustadt Klimaneutral 2040 document can be interpreted as an integrated climate action plan rather than a narrow sectoral policy. It connects energy transition, mobility transformation, spatial planning, and governance mechanisms within a single strategic framework aimed at achieving climate neutrality by 2040. This integrated design reflects an understanding that decarbonisation cannot be achieved through isolated measures but requires coordinated systemic change.

The strategy explicitly links interventions across key domains, including stationary energy systems, transport, land use, and waste management. By aligning energy policy with mobility reform and spatial development, the document promotes cross-sectoral coherence. Climate mitigation and adaptation are therefore embedded within broader urban transformation processes rather than confined to environmental regulation alone.

Holistic planning is further reinforced through the establishment of structured monitoring mechanisms and stakeholder involvement. The strategy combines measurable targets, data-driven evaluation, and workshop-based governance processes. This approach strengthens accountability and adaptive capacity, ensuring that climate actions remain aligned with long-term objectives while allowing for policy adjustment over time.

Importantly, the Klimaneutral 2040 roadmap builds upon and complements the broader STEP WN 2030+ urban development strategy. It functions as the operational climate pillar of the city's overall development concept rather than as an independent policy document. In this sense, the climate strategy institutionalises environmental transformation within the existing urban governance framework, reinforcing vertical and horizontal policy integration.

10.6 Integrated Summary of Analytical Findings

The Wiener Neustadt Klimaneutral 2040 roadmap represents a structured and operationally oriented climate governance framework that translates sustainability objectives into measurable and institutionally anchored actions. Its strongest contribution lies in shifting climate neutrality from a symbolic ambition to a managed transformation process supported by data, monitoring, and cross-sectoral coordination. By grounding its greenhouse gas inventory in the internationally recognised GPC standard and establishing a structured monitoring system, the strategy enhances methodological credibility and comparability. From a governance perspective, digital empowerment functions primarily as an analytical and managerial tool, strengthening institutional capacity rather than generating user-facing technological innovation. This inward-oriented digitalisation reinforces administrative effectiveness but does not yet position climate governance as a driver of broader digital service transformation or destination competitiveness.

The accessibility dimension is embedded within a broader “just transition” framework, reflecting awareness of the distributive impacts of decarbonisation. By integrating social, ecological, and economic sustainability, the strategy recognises that climate action must remain socially legitimate and inclusive. Participatory workshops and stakeholder engagement processes support procedural accessibility and collective ownership. However, inclusivity is addressed primarily at the level of principle and governance process. While the expansion of low-carbon mobility and energy alternatives enhances access to sustainable options, the strategy could benefit from clearer articulation of how vulnerable groups are systematically protected or supported in the transition. Thus, social justice is acknowledged conceptually but operational mechanisms for redistribution or targeted support remain less visible.

Sustainability is the document’s central pillar and is operationalised through more than 200 measures spanning mobility, energy, waste, and governance. This comprehensive action plan reflects systemic thinking and recognises that decarbonisation requires coordinated interventions across urban subsystems. The focus on photovoltaic expansion, fleet electrification, and mobility reform indicates strategic prioritisation of high-impact emission sectors. The inclusion of continuous monitoring further strengthens accountability and adaptive learning. Nevertheless, the breadth of measures raises questions about prioritisation, resource allocation, and implementation sequencing.

Cultural and creative dimensions receive limited explicit attention, appearing mainly as indirect outcomes of improved urban quality of life and strengthened social cohesion. While participatory governance may reinforce cultural resilience, the absence of a clear cultural sustainability narrative suggests that environmental transformation is framed primarily through technical and infrastructural lenses. Finally, the strategy’s holistic character constitutes one of its most robust features. By aligning energy transition, mobility reform, spatial planning, and governance mechanisms—and by explicitly building on the STEP WN 2030+ framework—the roadmap institutionalises climate action within the broader urban development architecture. In conclusion, Klimaneutral 2040 can be interpreted as a credible and governance-driven climate transition model for a secondary city. Its strengths lie in data-based management, systemic integration, and institutional embedding.

11 Summary Table of the Structured Document Analysis

Table 1: Summary Table of the Structured Document Analysis

Dimension	STEP WN 2030+ – Evidence	Klimaneutral 2040 – Evidence	Relational Implication
Digital Empowerment	Emphasis on integrated urban planning databases; land-use mapping; environmental monitoring; publicly accessible planning materials; intelligent mobility systems	GPC-based emissions inventory; structured monitoring system; emissions database; stakeholder workshops supported by shared data	Digital infrastructure strengthens transparency and institutional trust; enhances information symmetry between municipality and stakeholders; supports evidence-based relational coordination
Accessibility for All	Barrier-free public spaces; mixed-use urban form; participatory planning; citizen involvement in strategy development	“Just transition” principle; stakeholder consultation workshops; inclusive mobility alternatives; equitable energy transition framing	Inclusive governance reduces relational asymmetry; promotes perceived fairness; strengthens legitimacy and long-term stakeholder alignment
Sustainability	Horizontal integration of climate mitigation and adaptation; compact urban development; green space protection; sustainable mobility	200+ climate measures; sectoral coordination (energy, mobility, waste); measurable targets; continuous monitoring	Sustainability acts as a shared normative contract between actors; supports intergenerational governance trust; builds long-term relational stability
Culture & Creativity	“Lebendige Innenstadt”; heritage integration; multifunctional city centre; community space revitalisation	Indirect cultural reinforcement via social cohesion and participatory governance	Identity-based governance strengthens symbolic relationship capital; enhances resident–municipality emotional alignment; supports destination narrative coherence
Holistic Planning	Legally binding integrated planning framework; Strategic Environmental Assessment (SUP); multi-actor governance model	Operational climate pillar embedded within urban strategy; cross-sectoral integration; monitoring mechanisms	Institutional alignment reduces fragmentation; improves inter-organisational coordination; strengthens relational governance architecture

Source: Authors’ own compilation based on document analysis.

The table provides a structured comparison of two strategic documents—STEP WN 2030+ and Klimaneutral 2040—across five analytical dimensions: Digital Empowerment, Accessibility for All, Sustainability, Culture and Creativity, and

Holistic Planning. It systematically links concrete policy measures to their broader relational governance implications.

In the dimension of Digital Empowerment, both strategies emphasize data-driven planning tools, monitoring systems, and shared databases. These instruments enhance transparency and support evidence-based decision-making, thereby strengthening institutional trust and coordination between the municipality and stakeholders.

Under Accessibility for All, the documents highlight barrier-free infrastructure, participatory planning, and the principle of a “just transition.” These measures reduce relational asymmetries and promote perceived fairness, contributing to stronger stakeholder alignment and governance legitimacy.

In the Sustainability dimension, both strategies integrate climate mitigation and adaptation measures with measurable targets and cross-sectoral coordination. Sustainability functions here as a shared normative framework, reinforcing long-term commitment and intergenerational responsibility among governance actors.

The Culture and Creativity dimension underscores heritage integration, social cohesion, and participatory processes. These elements enhance symbolic and identity-based relationship capital, fostering emotional alignment between residents and municipal institutions.

Finally, Holistic Planning reflects legally binding frameworks, cross-sectoral integration, and structured monitoring mechanisms. Institutional alignment reduces fragmentation and strengthens relational governance architecture.

Overall, the table demonstrates that governance-led digital transformation does not merely introduce technological solutions; it restructures stakeholder relationships through transparency, inclusion, coordinated planning, and shared strategic direction.

12 Governance-Led Digital Transformation in Secondary Cities

12.1 Digitalisation as a Governance Instrument

The case of Wiener Neustadt demonstrates that in secondary cities digital transformation can function primarily as a governance instrument rather than as a market-driven technological innovation. In both the STEP WN 2030+ Urban Development Strategy and the Klimaneutral 2040 Climate Roadmap, digitalisation is embedded in data-driven decision-making, monitoring systems, and evidence-based planning. The emphasis lies on analytical capacity, transparency, and institutional coordination rather than on visitor-facing smart applications or tourism-oriented digital services.

This governance-led digitalisation model reflects a structural logic: digital tools are used to strengthen administrative effectiveness, policy coherence, and long-term accountability. The use of GPC-standard greenhouse gas inventories, environmental monitoring databases, and structured evaluation systems positions digital transformation as an enabler of institutional learning and adaptive governance. Digitalisation enhances regulatory and planning capacity but is not yet fully mobilised as a strategic instrument for destination branding, visitor management, or experiential co-creation.

12.2 Strategic Coherence Between Urban and Climate Strategy

A defining strength of the Wiener Neustadt case is the strong strategic coherence between the urban development strategy (STEP WN 2030+) and the Klimaneutral 2040 roadmap. The climate strategy does not operate as a separate environmental document but functions as the operational climate pillar of the broader urban development framework. This vertical and horizontal integration reinforces policy consistency and reduces fragmentation—an issue frequently observed in medium-sized cities with limited administrative capacity.

Climate mitigation, spatial planning, mobility reform, and governance mechanisms are systematically aligned. Sustainability is treated as a horizontal principle in the urban strategy and operationalised through more than 200 measures in the climate roadmap. This coherence increases implementation credibility and supports long-

term transformation trajectories. Nevertheless, the breadth of measures raises questions about prioritisation, sequencing, and resource allocation. Without clearly defined performance hierarchies and impact-weighted evaluation, strategic coherence may risk becoming administratively complex rather than strategically focused.

12.3 Institutional Capacity of Secondary Cities

The Wiener Neustadt case seems to challenge the common assumption that only large metropolitan areas can implement structured, data-driven sustainability transitions. The adoption of internationally recognised accounting standards, the establishment of monitoring frameworks, and the inclusion of stakeholder workshops indicate a relatively high level of institutional capacity for a secondary city. Governance structures appear capable of coordinating multi-sectoral interventions across mobility, energy, waste, and spatial planning.

At the same time, the strategies reveal typical structural limitations of secondary cities. Digital transformation is primarily institutional and infrastructural, while innovation ecosystems, creative industries, and tourism competitiveness are less explicitly integrated into the digital governance framework. Cultural sustainability appears as an indirect outcome of improved quality of life rather than as an actively managed strategic dimension. This suggests that institutional maturity in regulatory governance does not automatically translate into competitive positioning in the destination economy.

12.4 Implications for Urban Management

The case illustrates a governance-led model of digital transformation where sustainability and resilience are prioritised over market-driven smart destination branding. This resident-centred logic enhances long-term urban liveability and social legitimacy, which may serve as important preconditions for sustainable tourism development. However, the absence of explicit destination-oriented digital strategies may limit the city's ability to leverage sustainability achievements for competitive advantage in regional tourism markets.

For urban management in secondary cities, the key implication is that digital transformation should not be reduced to technological adoption. Instead, it must be embedded within institutional reform, monitoring capacity, and cross-sectoral integration. At the same time, governance-driven sustainability strategies would benefit from clearer prioritisation mechanisms, measurable performance indicators, and stronger linkage to innovation-based competitiveness. In summary, Wiener Neustadt provides a useful illustrative case of governance-led digital transformation, yet future development could further integrate digitalisation with destination management and economic positioning to enhance both resilience and competitiveness.

Based on the empirical findings, Figure 2 presents a simplified governance-led transformation pathway identified in the Wiener Neustadt case.

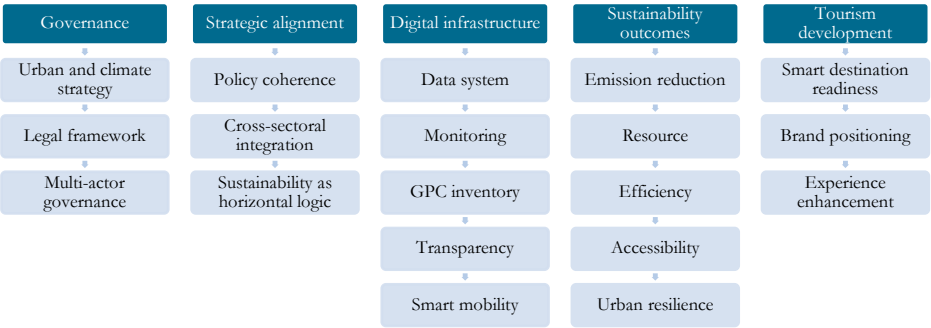


Figure 2: Governance-led model of digital transformation
Source: own editing

12.5 Short Conceptual Explanation

The model illustrates a governance-led pathway of digital transformation in a secondary city context. Rather than starting from technology or tourism innovation, the process begins with institutional governance structures anchored in legally adopted urban and climate strategies.

Strategic alignment between urban development and climate policy creates cross-sectoral coherence, ensuring that sustainability operates as a horizontal principle rather than a standalone objective. Digital infrastructure then functions as an

enabling mechanism—primarily through data systems, monitoring frameworks, and analytical tools—that strengthens institutional capacity and evidence-based decision-making.

These governance-driven digital capacities generate measurable sustainability outcomes, including resource efficiency, emission reduction, accessibility, and resilience. Tourism development can be interpreted as a downstream effect: a well-managed, sustainable, and data-informed urban environment may enhance smart destination readiness and long-term competitiveness.

The model supports the interpretation that in this case, digital transformation appears to be more governance-led than technology-led, with tourism benefits arising as a structural consequence of sustainability-oriented urban management.

12.6 Theoretical, Methodological and Policy Contributions Conceptual contribution

This study offers a conceptual reinterpretation of digital transformation in urban tourism as a governance-led process rather than a technology-driven innovation trajectory. By positioning sustainability as a horizontal organising principle and tourism development as a downstream outcome of institutional alignment, the paper extends smart tourism literature beyond ICT adoption and destination marketing. It contributes to governance scholarship by suggesting how strategic coherence between urban development and climate policy shapes sustainability-oriented transformation in secondary cities. Methodological contribution. Methodologically, the study advances smart tourism research by combining structured strategic document analysis with a multi-dimensional analytical framework derived from smart governance and European smart tourism policy pillars. By systematically comparing an urban development strategy with a climate neutrality roadmap, the research illustrates how governance alignment can be assessed in secondary cities through formal policy instruments. Policy contribution. From a policy perspective, the findings provide transferable insights for medium-sized cities seeking to embed digitalisation within long-term sustainability governance. The case of Wiener Neustadt illustrates that data-driven monitoring, cross-sectoral integration, and institutional coordination are preconditions for credible climate transition and smart destination readiness. At the same time, the study highlights the need for clearer

prioritisation mechanisms and stronger linkage between governance-driven sustainability and competitive destination positioning.

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TIME, EXPOSURE AND SOCIAL SUSTAINABILITY IN THE NATIONAL IDENTITY OF INTERNATIONAL STUDENTS

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This study examines how the duration of study abroad is associated with perceived changes in national identity. The aim was to address a gap in understanding whether time spent abroad may be linked to specific attitudinal shifts. The study uses a retrospective pre-post design with 308 international students in Hungary, grouped by time abroad, and analyzes perceived changes across four identity dimensions: national sentiment, patriotism, nationalism, and collective narcissism. While no significant between-group differences emerged, the within-group results suggested that perceived changes were concentrated in the more defensive and superiority-based dimensions of identity. Specifically, a significant decrease in nationalism and a marginal decrease in collective narcissism were observed in the three-or-more-years subgroup, while affective and pride-based dimensions remained stable or showed slight increases. This research contributes by identifying duration as a potentially relevant factor and by distinguishing between different dimensions of national identity in the study abroad context.

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1 Introduction

The relationship between studying abroad and the transformation of national identity is an increasingly important concern in international education research. As global student mobility accelerates, understanding how prolonged exposure to a foreign society shapes attachment to one's home country becomes more relevant. While existing research shows that international students often experience identity development, acculturation, and increased intercultural competence, these changes are neither uniform nor linear. Instead, they depend on multiple factors, including individual motivation, the host environment, and, critically, the duration of time spent abroad.

Among these, duration is emerging as a potentially relevant yet underexplored variable. Recent evidence suggests that only extended immersion, typically three or more years, may be sufficient to reshape more deeply rooted national attitudes. Such exposure has been linked to reductions in nationalism and marginal decreases in collective narcissism, whereas shorter stays appear insufficient to alter these more rigid dimensions (Szigeti et al., 2025).

Importantly, national identity is unlikely to change uniformly across its components. More affective and secure forms of attachment, such as national sentiment and patriotism, tend to be relatively stable, whereas defensive and superiority-based dimensions, such as nationalism and collective narcissism, may be more responsive to contextual influences. Accordingly, this study adopts a multidimensional approach, allowing us to distinguish between general identity change and more selective shifts in its rigid components.

This distinction is also relevant from a broader societal perspective. Although multicultural exposure is often associated with concerns about the erosion of national identity, theory suggests that constructive forms of attachment, particularly patriotism, are not necessarily weakened. Instead, intercultural experiences may primarily reshape more defensive and exclusionary elements.

1.1 Research gap and hypotheses

This focus on duration reveals two key gaps in the literature. First, while developmental and migration research examines identity over time, it rarely isolates voluntary, extended residence abroad as a primary explanatory factor. In contrast, study-abroad research typically emphasizes short-term outcomes and overlooks potential threshold-like patterns, where deeper changes emerge only after prolonged immersion.

Second, the most entrenched dimensions of national identity, particularly nationalism and collective narcissism, are usually treated as predictors rather than outcomes. Although widely linked to political behavior, prejudice, and conspiracy beliefs (Golec de Zavala, 2024; Cichoka & Cislak, 2020; Cislak & Cichoka, 2023; Marchlewska et al., 2022; Guerra et al., 2020), their potential to be reshaped through lived intercultural experience remains largely unexplored.

The present study addresses these gaps by (a) grouping international students based on duration of stay, including long-term residence, and (b) examining multiple dimensions of national identity simultaneously. This approach enables testing whether prolonged immersion is associated with selective changes in defensive forms of identity rather than a uniform transformation.

Accordingly, the following hypotheses were formulated:

- H1: International students report significant changes in national identity dimensions after studying abroad in Hungary.
- H2: Perceived changes in national identity differ across dimensions, such that affective attachment (national sentiment) shows a different trajectory than superiority- and defensiveness-based dimensions (nationalism and collective narcissism).
- H3: The duration of stay abroad is associated with the magnitude of perceived change in national identity dimensions.
- H4: Students with longer exposure (3+ years) exhibit greater decreases in superiority- and entitlement-based identity dimensions (nationalism and collective narcissism) compared to students with shorter stays.

2 Dimensions of national identity: national sentiment, patriotism, nationalism, and collective narcissism

Research distinguishes between various dimensions of national identity. Nationalism and collective narcissism are more resistant to change and may require prolonged immersion to shift, whereas other facets, such as intercultural competence and hybrid identity, may develop more rapidly. The literature also highlights the importance of distinguishing between these constructs in both measurement and intervention design.

The present study focuses on four distinct but related dimensions of national identity that are rarely examined together in the study abroad context.

National sentiment (or national attachment) is a broad, affective attachment to the nation: feelings of closeness, warmth, and satisfaction with the national ingroup, without implying hostility or superiority (Bakó & Szeberényi). Work differentiating national ingroup satisfaction from more defensive national attachments shows that mere satisfaction is psychologically distinct from nationalism and collective narcissism and is less strongly tied to prejudice. (Gustavsson, 2019; Zakirova, 2025; Szeberényi, 2025) The term is sparingly used in academic research, it was chosen to serve as a positive, general term for positive feelings towards one's own nation.

Patriotism is typically defined as a positive, value-laden commitment to the nation, compatible with critical reflection and not inherently exclusionary. Recent work distinguishes open patriotism from closed, ethnocentric nationalism and emphasizes its potential to support democratic, outward-looking forms of belonging. (Huddy & Khatib, 2007) At the same time, conceptual critiques warn that empirical scales often blur patriotism and nationalism and underplay contextual variation. (Bonikowski & DiMaggio, 2016; Nedzinskaite-Mitke & Stasiulis, 2022; Bitschnau & Mußotter, 2022)

Nationalism denotes a stronger belief in national superiority and a desire for the nation to dominate or be prioritized over others, often accompanied by exclusionary attitudes and support for invidious comparisons with other countries. Psychologically, nationalism is strongly associated with status competition and negative intergroup outcomes and can be empirically separated from benign national attachment. (Mayall, 2023; Bonikowski & DiMaggio, 2016; Fűrész et al, 2025)

National narcissism (collective narcissism) captures a defensive belief that the nation is exceptional yet insufficiently recognized by others, combining grandiosity with chronic sensitivity to disrespect. National narcissism predicts nationalism and support for populist, anti-democratic, or aggressive policies above and beyond secure national identification. It is linked to conspiracy beliefs, prejudice, and hostility, and is consistently distinguished from secure, non-narcissistic national identification. (Golec de Zavala et al., 2019; Golec De Zavala, 2023; Cichoka & Cislak, 2020; Cislak & Cichoka, 2023; Marchlewska et al., 2022)

By differentiating these four dimensions, the study moves beyond global “national identity” measures toward a more fine-grained view of how emotionally warm, critical, superiority-oriented, and defensive forms of national attachment may respond differently to extended residence abroad.

3 Time abroad and identity change

Growing cross-border student mobility has intensified interest in how study abroad experiences reshape national identity. Existing work shows that international experiences can foster intercultural competence, challenge stereotypes, and stimulate reflection on one’s own cultural background, but also that contact is often shallow and immersion incomplete. (Sobkowiak, 2019) Time abroad is usually treated as a control or linear predictor rather than a theoretically central variable, so the conditions under which extended immersion transforms core national attitudes remain poorly specified.

This gap in the study abroad literature is somewhat surprising, given that time has been central in developmental research on ethnic, national, and personal identity among migrant and minority youth, where longitudinal models track changes across several years in relation to school context, perceived fit, or acculturation experiences. (Mastrotheodoros et al., 2021; Gharaei et al., 2024) These studies highlight that national identity is dynamic and can evolve in response to social environments, but they typically focus on early adolescence in the receiving country rather than on voluntary student sojourners choosing to live abroad.

Work on study abroad and international education mostly investigates intercultural competence, contact patterns, and self-reflection, sometimes noting that sojourns can prompt reconsideration of home-country norms and identity. However, time abroad is usually operationalized in relatively short windows (e.g., one semester or one academic year) and linked to outcomes such as language gains, intercultural sensitivity, or stereotype change (Sobkowiak, 2019) rather than to differentiated forms of national attachment, nationalism, or national narcissism. Longer residence abroad, or comparisons across substantially different durations, are rarely theorized as potential threshold-like patterns for deeper shifts in entrenched national beliefs.

There is also a growing body of cross-sectional and longitudinal research on national identity and national narcissism that treats these constructs as relatively stable correlates of political attitudes, prejudice, or conspiracy beliefs, rather than as potential outcomes of international mobility. (Guerra et al., 2020; Cichoka et al., 2022; Cichoka & Cislak, 2020; Marchlewska et al., 2022; Guerra et al., 2020) Large, multi-country studies show that national narcissism varies systematically across national contexts (for example, being lower in more globalized societies), (Cichoka et al., 2022) suggesting that features of cross-national exposure matter. Yet, such work typically operates at the level of macro-indices of globalization, not at the level of individuals' accumulated time living abroad.

4 Methodology

4.1 Participants and Procedure

An online survey was distributed among international students studying in Hungary to collect data. The analysis included a total of 308 valid responses. Participants came from 56 different countries and were in different disciplines, study programs and levels, which made sure that their academic backgrounds and national origins were different for a more varied picture. Participation was voluntary and anonymous.

For the purposes of this study, we asked students how long they had lived and studied in Hungary, and we used that information to make three exposure groups: less than one year, one to two years, and three or more years. We designed these

categories to capture short-, medium-, and long-term immersion in the host country (Hungary).

4.2 Measures

Twelve statements that represented four theoretically different dimensions (national sentiment, patriotism, nationalism, and collective narcissism) were used to measure national identity. There were three items in each dimension.

National sentiment encompassed expressions of emotional attachment and constructive loyalty (e.g., profound attachment to one's country, endorsing the nation while remaining open to critique). Patriotism encompassed pride-associated sentiments, such as pride in historical context, progress, and national accomplishments. Nationalism evaluated comparative and superiority-oriented convictions (e.g., the conviction that one's nation is superior to the majority). Collective narcissism assessed defensive and entitlement-driven national sentiments (e.g., the conviction that the nation merits preferential treatment or is inadequately esteemed).

A retrospective pre-post format was used to measure perceived changes over time. Each participant rated each item twice: first, they recalled how they felt before they went abroad ("before") and then they reported how they feel now ("after"). We used a Likert-type scale to rate all of the items.

To get a composite score for each dimension, we took the average of the three items. Change scores were calculated by subtracting pre-mobility scores from post-mobility scores, with positive values signifying an increase and negative values signifying a decrease in the corresponding identity dimension.

4.3 Analysis

There were two steps in the data analysis. First, paired-sample t-tests were performed on the entire sample to evaluate the overall differences between pre- and post-mobility scores across the four identity dimensions. Cohen's *d* was used to figure out the size of the perceived change by calculating effect sizes.

Second, to investigate the relationship between exposure duration and variations in perceived identity change, one-way analyses of variance (ANOVA) were performed on the calculated change scores among the three time-abroad groups. Post hoc comparisons were used to look at differences between groups when it made sense to do so. Before comparing groups, we checked to see if the variances were the same. IBM SPSS Statistics 27 software was used for the analyses.

We used standard statistical methods for all of the analyses, and we looked at statistical significance at conventional thresholds.

While the study does not directly measure social sustainability as a separate construct, it approaches it as an interpretative framework. Specifically, shifts in national identity dimensions are examined in terms of their potential implications for socially sustainable attitudes, such as openness, reduced defensiveness, and compatibility with intercultural coexistence.

5 Results

5.1 Overall perceived pre–post change in national identity dimensions

Across the full sample of international students in Hungary ($N = 308$), the retrospective pre-post comparisons suggest that national identity does not shift uniformly. Instead, the observed pattern is characterized by broad stability with small, directionally meaningful movements in selected dimensions (Table 1). On average, national sentiment increased slightly from pre to post, patriotism remained essentially unchanged, nationalism remained stable, and collective narcissism decreased slightly. These descriptive trends already signal that studying abroad may affect different components of national identity in distinct ways rather than producing a single general “increase” or “decrease” in national identification.

Paired-sample tests (Table 2) confirm this overall profile. National sentiment showed a marginally significant change, indicating a small increase in emotional attachment and constructive loyalty ($p = .053$). Importantly, this effect was small in magnitude (Cohen’s $d = -0.111$ based on the pre-post difference direction), suggesting that the shift is subtle rather than transformative. Patriotism did not change significantly ($p = .677$), indicating that pride in national history, national

development, and national achievements remained stable across time. Nationalism also did not change ($p = .974$), showing that attitudes related to national superiority or unconditional support toward one's country were not generally affected in the overall sample. Finally, collective narcissism showed a marginal decrease ($p = .089$) with a small effect size ($d = 0.097$), suggesting a weak but directionally consistent reduction in defensive entitlement-based national attitudes.

Table 1: Descriptive statistics and mean change for national identity dimensions (N=308)

Identity dimensions	Pre M (SD)	Post M (SD)	Change (Post-Pre)
National Sentiment	3.56 (0.70)	3.62 (0.77)	+0.06
Patriotism	3.81 (0.89)	3.82 (0.90)	+0.02
Nationalism	2.77 (0.98)	2.77 (1.01)	+0.00
Collective narcissism	3.07 (0.86)	3.02(0.95)	-0.05

Source: own editing with SPSS software

Table 2: Paired-samples t-tests for pre-post change (N=308)

Identity dimensions	Mean diff (Pre-Post)	95% CI (Pre – Post)	t(df)	p	Cohen's d
National Sentiment	-0.060	[-0.120, 0.001]	-1.942 (307)	.053	-0.111
Patriotism	-0.015	[-0.087, 0.056]	-0.417 (307)	.677	-0.024
Nationalism	-0.001	[-0.066, 0.064]	-0.033 (307)	.974	-0.002
Collective narcissism	0.052	[-0.008, 0.112]	1.707 (307)	.089	0.097

Source: own editing with SPSS software

Taken together, the full-sample analysis suggests that study abroad in Hungary is not associated with widespread shifts in national identity across all dimensions. Instead, it is associated with modest movement at the level of national sentiment and collective narcissism, while patriotism and nationalism remain stable in the aggregate. This multidimensional outcome is theoretically meaningful: it implies that affective attachment and defensive group entitlement can move independently of pride-based patriotism and superiority-based nationalism, and that the “national identity” construct may be too heterogeneous to interpret as a single trajectory.

5.2 Duration of stay and between-group comparisons

A central aim of this study was to examine whether time spent abroad differentiates perceived identity change, under the assumption that longer exposure may be necessary for shifts in deeper and more resistant attitudes. To test this, change scores were compared across three time-abroad groups: less than one year, one to two years, and three or more years. The between-group analyses using ANOVA found no statistically significant differences for any of the four identity dimensions (Table 3). In other words, when the question is asked directly as “Do longer-stay students change more than shorter-stay students?”, the answer is not supported by between-group significance testing in this sample.

Table 3: One-Way ANOVA on change scores by time abroad (N=308)

Identity dimensions change score	F (2,305)	p
National Sentiment change	0.391	0.677
Patriotism change	0.067	0.935
Nationalism change	0.522	0.594
Collective narcissism change	0.355	0.702

Source: own editing with SPSS software

This finding is important because it suggests that any duration effect is not strong enough to emerge as a clear group-level separation. The lack of significant ANOVA results may reflect several realities: 1) large individual variability in identity trajectories, 2) subtle effect sizes that require more statistical power or more sensitive measures, and 3) the possibility that duration does not operate as a linear driver of identity change. It also suggests that conclusions about “time abroad” should not be framed as deterministic. The data do not support a simple dose-response model in which each additional time category yields progressively stronger change across all dimensions.

However, the absence of between-group significance does not imply that duration is irrelevant. It implies that duration does not generate clean, strong, and consistent differences in mean change across groups under conventional significance thresholds. For interpreting identity change, this distinction matters: identity processes can display meaningful patterns that do not appear as strong between-group effects, especially when subgroup sizes are modest and changes are small.

5.3 The within-group pattern by time abroad

Although ANOVA did not reveal statistically significant group differences, the descriptive change scores by time group reveal a coherent within-group pattern that helps explain why the full-sample results look mixed (Table 4). In particular, the 3+ years group shows negative change scores in nationalism and collective narcissism (indicating decreases), whereas the shorter-duration groups show either minimal change or slight increases. The pattern is modest, but it is consistent with the conceptual expectation that the most resistant dimensions of national identity may require prolonged immersion to soften.

Table 4: Descriptive change scores by time abroad group (N=308)

Identity dimensions change score	<1 year (n=105) M (SD)	1–2 years (n=120) M (SD)	3+ years (n=83) M (SD)
National Sentiment change	0.025 (0.544)	0.089 (0.571)	0.064 (0.481)
Patriotism change	0.013 (0.567)	0.003 (0.643)	0.036 (0.717)
Nationalism change	0.013 (0.529)	0.025 (0.540)	−0.056 (0.694)
Collective narcissism change	0.010 (0.727)	−0.003 (0.663)	−0.068 (0.591)

Source: own editing with SPSS software

This is clarified further by within-group paired comparisons (Table 5). For nationalism, only the 3+ years group shows a statistically significant pre-post change ($p = .035$), reflecting a decrease in nationalism within that group. The effect size is small-to-moderate by the standards of social identity change research ($d = 0.234$), and the direction is theoretically meaningful: the longest-exposure group becomes less likely to endorse superiority-based or unconditional national claims. The shorter groups show no significant changes, although the 1–2 years group trends toward an increase in nationalism ($p = .097$), which may reflect a transitional period of identity defensiveness for some students, or simply random variability.

For collective narcissism, the 3+ years group shows a marginal decrease ($p = .057$), again aligning with the idea that defensive entitlement-based beliefs may soften after prolonged exposure. The shorter groups do not show meaningful movement in this dimension, with p -values far from conventional thresholds. This provides a plausible explanation for the weak full-sample trend: the overall marginal decrease appears to be driven largely by the long-duration subgroup.

Table 5: Within-group paired t-tests highlighting the long-term group pattern (N=308)

Identity dimensions	Time group	Pre M	Post M	Mean diff (Pre – Post)	t(df)	p	Cohen's d
National Sentiment	<1 year	3.616	3.683	–0.067	–1.439 (104)	.153	–0.140
National Sentiment	1–2 years	3.542	3.558	–0.017	–0.321 (119)	.749	–0.029
National Sentiment	3+ years	3.520	3.635	–0.115	–1.865 (83)	.066	–0.203
Patriotism	<1 year	3.829	3.918	–0.089	–1.761 (104)	.081	–0.172
Patriotism	1–2 years	3.769	3.817	–0.047	–0.857 (119)	.393	–0.078
Patriotism	3+ years	3.837	3.714	0.123	1.431 (83)	.156	0.156
Nationalism	<1 year	2.813	2.844	–0.032	–0.663 (104)	.509	–0.065
Nationalism	1–2 years	2.808	2.892	–0.083	–1.674 (119)	.097	–0.153
Nationalism	3+ years	2.671	2.508	0.163	2.145 (83)	.035	0.234
Collective narcissism	<1 year	3.146	3.137	0.010	0.222 (104)	.825	0.022
Collective narcissism	1–2 years	3.064	3.003	0.061	1.031 (119)	.305	0.094
Collective narcissism	3+ years	2.984	2.889	0.095	1.928 (83)	.057	0.210

Source: own editing with SPSS software

For national sentiment, the 3+ years group again shows the strongest upward trend ($p = .066$), while shorter groups show minimal or non-significant change. This suggests that prolonged study abroad may coincide with a slight increase in constructive attachment to one's home country rather than erosion of belonging. Importantly, this rise in sentiment coexists with reductions in defensive and superiority-oriented dimensions, supporting the interpretation that identity change is not “less national” overall, but “less defensive and more reflective” in the long term.

Patriotism behaves differently. The pattern across groups is not consistent and does not support a clear duration-based mechanism. The less-than-one-year group shows a marginal increase ($p = .081$), while the 3+ years group shows a non-significant decrease ($p = .156$). Combined with the null full-sample effect (Table 2), this suggests that pride in national history and achievements may be relatively stable, and potentially shaped more by stable socialization and cultural narratives than by the study abroad experience itself.

5.4 Integrating the findings across dimensions

The most informative aspect of these results is the divergence between identity dimensions. National sentiment trends upward, nationalism trends downward only in the longest-duration group, and collective narcissism shows a marginal decrease in that same group, while patriotism remains largely stable. This pattern offers a nuanced account of identity change that is more nuanced than general accounts that frame study abroad mainly as increasing global citizenship.

Rather than replacing national identity with cosmopolitan identity, the data suggest the possibility of a selective restructuring of national identity content. Affective attachment and constructive loyalty can slightly strengthen over time abroad, potentially through mechanisms such as nostalgia, reflective comparison, or renewed appreciation of one's home culture. At the same time, prolonged intercultural exposure may reduce defensiveness and superiority-based beliefs, which are conceptually closer to nationalism and collective narcissism.

This distinction matters because it speaks to social sustainability implications without forcing them. In multicultural environments, socially sustainable outcomes are not necessarily about weakening national identity. They are about whether national identity becomes compatible with pluralism and intercultural coexistence. A small reduction in rigid and entitlement-based attitudes among long-term sojourners can be interpreted as movement toward more socially compatible identity orientations, while the preservation or slight strengthening of sentiment suggests that this does not require detachment from one's national belonging.

Importantly, these within-group patterns should be interpreted as descriptive rather than as statistically confirmed differences between duration groups. While the observed trends are theoretically consistent, the absence of significant between-group effects in the ANOVA analysis means that conclusions regarding duration as a determining factor should be treated with caution.

6 Conclusions

This study set out to examine whether studying abroad in Hungary is associated with changes in national identity among international students, and whether the duration of exposure plays a role in shaping these changes. Importantly, the results indicate that national identity is not a monolithic construct and does not change uniformly across its dimensions.

Regarding H1, the hypothesis that studying abroad would be associated with significant perceived changes in national identity dimensions received only partial support. In the full sample, national sentiment showed a marginal increase, while collective narcissism showed a marginal decrease. Patriotism and nationalism remained statistically stable. Thus, while movement was observable in certain components, there was no evidence of broad or dramatic transformation across all dimensions. National identity appears largely stable, with only subtle adjustments emerging over time.

H2, proposing that different identity dimensions would follow different trajectories, was supported. The findings clearly demonstrate divergence across components. Affective attachment to the nation (national sentiment) tended to increase slightly, whereas defensive and superiority-based dimensions (particularly collective narcissism and, in specific subgroups, nationalism) showed decreasing tendencies. Patriotism remained comparatively stable. This multidimensional pattern suggests that study abroad may influence the qualitative structure of national identity rather than its overall strength. Emotional attachment can coexist with reduced defensiveness, supporting the argument that national belonging and openness are not mutually exclusive.

H3, which predicted that duration of stay would be associated with magnitude of perceived change, was not supported at the between-group level. One-way ANOVA analyses revealed no statistically significant differences in change scores across the three duration groups. Time abroad alone does not function as a strong or deterministic predictor of identity change. This finding cautions against simple “exposure equals transformation” models and highlights the complexity of identity development in intercultural settings.

However, H4 received partial support in within-group analyses. Students who had spent three or more years abroad exhibited a significant decrease in nationalism and a marginal decrease in collective narcissism. These effects were not present in shorter-duration groups. Although the between-group differences did not reach statistical significance, the within-group pattern suggests that prolonged immersion may be associated with gradual softening of superiority-based and entitlement-based national attitudes. Importantly, this reduction occurred without a corresponding erosion of national sentiment. In fact, national sentiment showed its strongest upward trend in the longest-duration group.

Taken together, the findings suggest that long-term study abroad may be associated with subtle shifts in the composition of national identity rather than its overall weakening. Specifically, defensive and superiority-based elements may diminish, while affective attachment remains stable or even strengthens slightly. This distinction is theoretically significant. It implies that intercultural exposure may reduce rigid or exclusionary components of national identity without undermining belonging or loyalty.

These patterns should be interpreted with caution. The observed effects are small in magnitude, and most between-group differences are not statistically significant. Accordingly, the findings are best understood as indicative of subtle, dimension-specific tendencies rather than strong or generalizable transformations.

These findings have implications for social sustainability. While social sustainability is not directly measured in this study, the observed pattern, characterized by stable or slightly increasing affective attachment alongside reductions in defensive and superiority-based dimensions, may reflect identity configurations that are more compatible with pluralism and intercultural coexistence.

7 Summary

This study contributes to the literature by showing that perceived national identity change during study abroad appears to be dimension-specific, subtle, and non-uniform. Across the full sample, national identity remained broadly stable, with only marginal shifts observed in national sentiment and collective narcissism. Duration

of stay did not produce statistically significant between-group differences, indicating that time abroad alone is insufficient to explain identity transformation.

Nevertheless, an interesting within-group pattern emerged among long-term sojourners. Students who had spent three or more years abroad showed evidence of decreasing nationalism and marginal reductions in collective narcissism, alongside slight increases in national sentiment. However, these findings should be interpreted cautiously, as the study does not provide statistically significant between-group evidence for a strong duration effect. Rather, the results point to subtle, exploratory patterns that require further confirmation.

Rather than depicting study abroad as a process of identity loss or replacement, the results suggest the possibility of selective perceived shifts in identity content. National belonging can remain intact while becoming less superiority-oriented and less entitlement-driven. Since social sustainability was not directly measured, this interpretation should be understood as an implication rather than a central empirical finding. Still, the observed patterns may be relevant for understanding how multicultural experiences can support forms of national identity that are more compatible with pluralism and coexistence, without requiring detachment from national roots.

This study has several limitations. Most importantly, the retrospective pre-post design means that the research captures perceived or reconstructed change rather than directly measured longitudinal change. Participants were asked to recall their pre-mobility attitudes, which may introduce recall bias, post-hoc rationalization, or the influence of current identity states on past self-assessments. In addition, the study relies on self-reported measures, which may be affected by social desirability bias, especially in relation to sensitive constructs such as nationalism and collective narcissism. Future longitudinal research using repeated measurements would be needed to confirm whether the observed tendencies reflect actual attitudinal change over time.

Overall, this study provides exploratory empirical support for a multidimensional understanding of national identity change and lays the foundation for further investigation into the psychological and contextual mechanisms that may explain who changes, how, and under what conditions.

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DETERMINANTS OF NATIONAL IDENTITY AMONG INTERNATIONAL STUDENTS ABROAD

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This study examines which factors shape national identity during study abroad, focusing on psychological, social, and institutional mechanisms. Using a cross-sectional survey design, data were collected from 308 international students studying in Hungary. Multiple linear regression analyses were conducted to examine how identity strain, intercultural engagement, host-country evaluations, and institutional satisfaction relate to post-mobility levels of national sentiment, patriotism, nationalism, and collective narcissism. The findings indicate that identity strain variables are the most consistent predictors of nationalism and collective narcissism. In contrast, greater international orientation and interaction with international peers are associated with lower levels of exclusionary national identity, while evaluations of the host country's political, economic, and social conditions show inconsistent effects. The results suggest that national identity during study abroad is driven primarily by internal identity processes and relational exposure rather than host-country characteristics.

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1 Introduction

Socially sustainable higher education depends not only on access and inclusion, but on how international experiences shape the ways students relate to their own and others' national groups.

International student mobility is a defining feature of higher education today. Study abroad is commonly associated with intercultural learning and personal growth, but it also intensifies identity reflection. Living outside one's home country often makes national belonging louder, prompting individuals to reassess their relationship to it. (Sobkowiak, 2019)

National identity is multidimensional, encompassing affective attachment (sentiment), constructive pride (patriotism), superiority beliefs (nationalism), and defensive concerns about collective recognition (collective narcissism) (Golec de Zavala, 2024). While international exposure is often assumed to weaken narrow-minded attitudes, findings are mixed: some studies point to greater openness, others to strengthened in-group identification under perceived uncertainty or threat. Empirical studies of study-abroad participants thus report both increased openness and, in some conditions, heightened in-group identification, especially when students perceive uncertainty or threat in the host environment. (Sobkowiak, 2019)

1.1 Research gap and hypotheses

Existing research on study abroad outcomes rarely examine differentiated effects on multiple dimensions of national identity. Studies often treat national identification as unidimensional or focus on intercultural competence, neglecting how psychological strain, relational exposure, and contextual assessments operate together. (De Lise et al., 2025) It also remains unclear whether different identity dimensions respond differently to mobility experiences, whether strain amplifies defensive attitudes, for instance, or whether peer contact mitigates them.

This study addresses these gaps by analyzing twelve post-mobility national identity statements across four conceptual dimensions. Using item-level regression models, it captures nuanced variation in how psychological, relational, and institutional factors shape identity expression among international students in Hungary.

Accordingly, the following hypotheses were formulated:

- H1: Higher levels of identity strain is associated with stronger post-mobility national identification.
- H2: Greater intercultural engagement and international orientation are associated with lower levels of exclusionary national identity.
- H3: Evaluations of host-country political, economic, and social conditions are associated with post-mobility national identity.
- H4: Psychological factors related to identity strain account for greater variance in national identity than contextual and institutional factors.

2 Dimensions of national identity

Contemporary research agrees that national identity is multidimensional rather than a single attitude of “feeling national” (Bonikowski & DiMaggio, 2016; Ariely, 2020; May, 2023). Four closely related, but empirically distinct, dimensions are especially relevant for international students: national sentiment, patriotism, nationalism, and collective narcissism.

National sentiment refers to basic feelings of belonging, attachment, and commitment to the national community, including emotional ties and a sense of membership in a political unit (Naz et al., 2025). It captures whether the nation is an important part of the self-concept, without specifying how the nation is defined or how it should relate to others (Bonikowski & DiMaggio, 2016; May, 2023). This kind of diffuse attachment is often considered a precondition for other, more specific forms of national identity such as pride or chauvinism (May, 2023). Several works show that ingroup satisfaction psychologically differs from nationalism and collective narcissism while also assuming less prejudice (Gustavsson, 2019). It must be mentioned that national sentiment is less frequently used as a dimension for national identity research (compared to patriotism, nationalism and collective narcissism), in this research it was used as a more generic, positive attitude toward someone’s own nation and nationality.

Patriotism is typically defined as a positive, affective attachment to one’s country, expressed as pride, loyalty and a willingness to contribute to the national community (Huddy & Khatib, 2007; Ariely, 2020). Political psychology distinguishes such “secure” national identification from more defensive or exclusionary forms

(Marchlewska et al., 2022; Cislak & Cichoka, 2023). Patriotism can be civic and inclusive, focused on institutions, values and achievements, rather than on ethnic boundaries (Bonikowski & DiMaggio, 2016; Ariely, 2020). Empirically, patriotism is associated with civic engagement and can be unrelated or even negatively related to hostility toward outgroups when separated from more chauvinistic attitudes (Huddy & Khatib, 2007; Marchlewska et al., 2022; Golec de Zavala, 2024).

Nationalism usually entails the belief that one's nation is superior and should have priority over others, often accompanied by restrictive criteria for membership and a willingness to assert national dominance (Bonikowski & DiMaggio, 2016; Ariely, 2020; Golec de Zavala, 2024). Studies measuring multiple facets of nationalism identify elements such as strong national pride, strict boundary definitions, and invidious comparisons to other nations (Bonikowski & DiMaggio, 2016; May, 2023). Nationalism therefore represents a more exclusionary and competitive form of national identity than either national sentiment or benign patriotism.

Collective narcissism refers to an exaggerated, insecure belief in the group's greatness, combined with a chronic expectation that others fail to appreciate and respect the group sufficiently (Cichoka & Cislak, 2020; Federico et al., 2021; Cislak & Cichoka, 2023). In the national domain, it manifests as the conviction that the nation is exceptional and entitled to special recognition, yet constantly disrespected. Factor-analytic work shows that collective narcissism is distinct from both nationalism and simple satisfaction with the nation, even though it often overlaps with them (Federico et al., 2021). Unlike secure patriotism, national narcissism is reliably linked to intergroup hostility, populist support, social cynicism and resistance to criticism of the nation. When secure national identification is statistically separated from narcissism, patriotism appears compatible with democratic values and inclusive attitudes, whereas the narcissistic component drives defensive, exclusionary responses (Marchlewska et al., 2022; Cislak & Cichoka, 2023; Golec de Zavala, 2024).

The literature thus supports treating national sentiment, patriotism, nationalism and collective narcissism as related but distinguishable dimensions, which can have different predictors and consequences in mobility contexts (Bonikowski & DiMaggio, 2016; Ariely, 2020; Marchlewska et al., 2022; Federico et al., 2021; May, 2023; Golec de Zavala, 2024).

3 Determinants of national identity change during study abroad

Research on international students and sojourners shows that national identity is not fixed; it is reshaped by psychological processes, social participation, and institutional and contextual conditions during mobility (Bethel et al., 2020; Raja et al., 2021; Chen, 2023; Teng et al., 2023; Vesković Anđelković, 2024). For students abroad, these factors can either foster inclusive, secure forms of national attachment or reinforce defensive nationalism and collective narcissism.

3.1 Psychological factors: identity strain, needs, and integration

Life transitions such as migration or study abroad introduce substantial identity strain. Students must reconcile pre-existing self-views with new cultural expectations, which can challenge continuity and coherence of the self (Raja et al., 2021; Li, 2025). Longitudinal work with newly arrived international students shows that satisfaction of basic psychological needs (belonging, competence, autonomy) in both heritage and host cultural groups predicts more identity integration, where multiple cultural identities are experienced as compatible and coherent. In contrast, perceived discrimination or chronic threat fosters identity compartmentalization or dominance of a single identity, often privileging the national or ethnic in-group over others (Amiot et al., 2017).

For some international students, identity dislocation manifests as confusion about “who they are” and tension between heritage and host norms, with consequences for mental health (Lim, 2024). When internal needs for recognition and esteem are unmet, identification with the nation can become defensive and narcissistic: students may seek psychological security in an idealized national in-group and become hyper-sensitive to perceived slights against it (Cichoka & Cislak, 2020; Federico et al., 2021; Marchlewska et al., 2022; Cislak & Cichoka, 2023). This pattern is consistent with broader evidence that collective narcissism helps manage individual psychological needs but undermines both intra- and intergroup relations (Cichoka & Cislak, 2020; Federico et al., 2021).

Psychological orientation toward openness also matters. Students who frame study abroad as an opportunity for exploration, and who develop hybrid or “open-ended” identities, tend to move away from rigid self-other dichotomies (Teng et al., 2023;

Li, 2025). Conversely, those seeking stability in familiar categories may strengthen a more closed national identity in response to perceived otherness and uncertainty (Raja et al., 2021; Teng et al., 2023; Lim, 2024).

3.2 Social and relational factors: contact, networks, and participation

Identity change is strongly mediated by patterns of social participation. Qualitative work with British students in China shows that those who actively engage with local peers, use their “otherness” as a resource, and invest in language learning often develop more complex, open identities that integrate aspects of both home and host cultures (Teng et al., 2023). Students who remain within co-national circles or avoid deep cultural contact tend instead to reinforce pre-existing national boundaries and “self-other” oppositions (Raja et al., 2021; Teng et al., 2023; Li, 2025).

The composition of social networks is crucial. Studies of international students’ identity development and cultural identity find that co-national and multinational friendships, extracurricular activities, and social skills are significant predictors of stronger (and more positive) cultural/national identification with the host environment (Raja et al., 2021; Meng, 2023). At the same time, strong national identity may lead students to preferentially seek co-nationals for support, which can increase emotional security but limit intercultural engagement and maintain sharper in-group/out-group distinctions (Naz et al., 2025). These patterns align with broader findings that secure identification can coexist with openness, whereas defensive national narcissism is linked to distrust and hostility toward outgroups (Cislak & Cichoka, 2023; Golec de Zavalá, 2024).

3.3 Institutional context and support

Institutional environments shape how psychological and social processes play out. Universities that provide inclusive teaching, culturally diverse activities, and psychological support can buffer acculturative stress and facilitate constructive identity work (Roy & Al Harthy, 2022; Meng, 2023; Naz et al., 2025; Li, 2025).

Conversely, restrictive communication environments or weak support structures can exacerbate identity threats. International students in China reported that disconnection from prior social networks (e.g., via internet restrictions) intensified

early identity threats, until new memberships with co-national and multinational peers were formed (Raja et al., 2021). Similarly, classroom norms and assessment practices that implicitly privilege one culture may reinforce feelings of inferiority or exclusion among international students and heighten identity strain (Lim, 2024).

3.4 Host country characteristics and macro-context

Comparative and bibliometric reviews of intercultural adaptation research emphasize that, globally, core themes recur (adjustment, acculturative stress, identity and social support) but regional emphases differ (Zhao, 2020; Alshammari et al., 2023; Fitria et al., 2025). In some contexts, national identity is framed more civically, supporting secure patriotism and openness; in others, discourses of external threat or disrespect encourage more defensive, potentially narcissistic nationalism, which can be activated by perceived criticism during study abroad (Zhang & Ren, 2024; Fitria et al., 2025; Naz et al., 2025). The same structural features (e.g., language distance, racialized hierarchies, geopolitical tensions) can thus either motivate critical reflection and more complex identities or fuel re-entrenchment of exclusionary national narratives.

4 Methodology

4.1 Research design and sample

The study used a survey-based approach to explore what shapes national identity among international students in Hungary. Researchers gathered data from 308 students enrolled at Hungarian universities, with participation being both anonymous and voluntary. The respondents came from a range of different countries and were at various points in their time abroad. The survey was administered online and responses were collected from my current students, alumni, dormitory residents, and contacts reached through academic networks across several Hungarian universities. Data collection took place throughout November 2025.

4.2 Measures and independent variables

The questionnaire was developed by operationalizing the key constructs identified in the literature and the research design. Each construct was translated into concrete survey items, resulting in a combination of Likert-scale statements and binary

(yes/no) questions. Likert-scale items were used to capture attitudes and perceptions related to national identity and mobility experiences, whereas binary questions targeted behavioral and contextual aspects, such as interaction patterns and practical experiences abroad. Most items were developed specifically for this study rather than directly adopted from existing scales, to ensure closer alignment with the research context. Prior to full data collection, the questionnaire was pre-tested with a small group of international students to assess clarity, wording, and overall coherence; minor adjustments were made based on feedback.

To measure national identity after mobility, the study used twelve statements covering four key themes: national sentiment, patriotism, nationalism, and collective narcissism. (Golec de Zavala, 2024; Cichoka & Cislak, 2020; Cislak & Cichoka, 2023) Each theme included three items.

Respondents rated their agreement on a Likert scale (1-5). Since responses varied quite a bit across items, the analysis looked at individual items rather than just grouping them into broader scores.

In terms of independent variables, the study looked at four main groups of factors:

- Identity strain

This captured psychological tension related to studying abroad, including mental strain tied to identity, feeling that the experience abroad led to more loss than gain, feeling more connected to one's home country, and uncertainty about oneself.

- Intercultural engagement

These items measured how often students interacted with other international students or locals, and whether they felt their international outlook had grown.

- Views on the host country

Students were asked about their perceptions of Hungary's government, living standards, how friendly they found Hungarians, and practical challenges like dealing with bureaucracy.

- Satisfaction with their university

This was included to see whether institutional experiences played a role.

Control variables like political orientation (conservative or liberal) and religiosity were also considered to ensure more accurate results.

4.3 Analysis

To explore the data, the researchers ran twelve separate regression models, one for each statement about national identity after studying abroad. All the predictor variables were entered into the models at the same time to see how much each one contributed independently.

This setup made it possible to check if certain factors had similar effects across related statements. The overall fit of each model was assessed using R^2 and F statistics, and standardized beta coefficients helped show which predictors had the strongest influence.

Since earlier analysis revealed that the effects of predictors could vary even within the same conceptual group, the study focused on interpreting results at the level of individual statements. This approach helped avoid lumping things together in a way that might hide important differences.

5 Results

To examine how psychological, social, and contextual factors shape national identity after studying abroad, multiple linear regression analyses were carried out. Twelve separate models were run—one for each individual item across the four identity dimensions. All models turned out to be statistically significant, which made it possible to systematically compare how different predictors influenced each aspect of identity.

5.1 Model fit across identity dimensions

Table 1 presents the overall fit indices for the twelve regression models estimated at the item level. All models were statistically significant ($p < .001$), indicating that the combined set of predictors explained a meaningful proportion of variance across all national identity components.

The strongest explanatory power emerged for the item “I feel strong attachment to their country” ($R^2 = .433$), suggesting that nearly 43% of the variance in attachment can be accounted for by the included psychological, social, and contextual variables. Substantial variance was also explained for more exclusionary nationalism items, such as “The world would be a better place if everyone was like my country” ($R^2 = .355$) and “I support my country even if it acts wrongly towards others” ($R^2 = .336$).

Table 1: Regression model fit summary (N=308)

Dependent Variable	Dimension	R ²	Adj. R ²	F
Strong attachment	National sentiment	0.433	0.393	10.67
Support but criticize	National sentiment	0.22	0.164	3.93
Rather citizen	National sentiment	0.329	0.281	6.85
Proud – history	Patriotism	0.244	0.19	4.5
Proud – developing	Patriotism	0.245	0.191	4.53
Proud – achievements	Patriotism	0.172	0.112	2.89
Better than most	Nationalism	0.271	0.219	5.2
Better if everyone like us	Nationalism	0.355	0.308	7.66
Support even if wrong	Nationalism	0.336	0.288	7.06
Special treatment	Collective narcissism	0.309	0.259	6.23

Source: own editing with SPSS software

Patriotism-related items showed moderate explanatory power (R^2 ranging from .172 to .245), while collective narcissism items were explained to a somewhat lesser extent (R^2 between .240 and .309). The lowest explained variance appeared for pride in

national achievements ($R^2 = .172$), indicating that this dimension may be less strongly tied to the examined predictors.

These results suggest that the selected predictors account more strongly for affective attachment and exclusionary nationalism than for pride-based or grievance-based identity components. This pattern provides initial support for the idea that identity change during study abroad is particularly associated with emotionally and normatively loaded aspects of national identification rather than purely symbolic pride elements.

5.2 Identity strain predictors

As shown in Table 2, identity strain variables demonstrated differentiated but theoretically coherent associations across the twelve identity items. Among these, perceived increased connectedness to the home country emerged as the most consistent predictor. It was positively associated with strong attachment ($\beta = .415$, $p < .001$), preference for home citizenship ($\beta = .330$, $p < .001$), all three patriotism indicators ($\beta = .175-.207$, $p \leq .013$), and multiple exclusionary nationalism and narcissism items. This pattern indicates that perceived reconnection functions as a general amplification mechanism, strengthening both affective belonging and more rigid identity expressions.

Psychological strain related to national identity also showed systematic effects, particularly for exclusionary components. It significantly predicted strong attachment ($\beta = .184$, $p = .002$), citizenship preference ($\beta = .162$, $p = .013$), superiority-based beliefs (e.g., “the world would be a better place if everyone was like my country,” $\beta = .167$, $p = .009$), and entitlement-oriented attitudes (e.g., “my country deserves special treatment,” $\beta = .181$, $p = .006$). These findings suggest that identity strain is associated less with symbolic pride and more with defensive and normatively rigid forms of identification, consistent with compensatory identity mechanisms.

Perceiving mobility as a loss (“I lost more than won by moving to Hungary”) displayed a more selective pattern. It was unrelated to attachment and pride but significantly predicted exclusionary nationalism and collective. This indicates that negative mobility evaluations are linked primarily to grievance-based identity reinforcement rather than to strengthened belonging per se.

In contrast, generalized self-uncertainty showed minimal and inconsistent associations, suggesting that diffuse identity instability does not systematically translate into heightened national identification in this context.

Taken together, the results indicate that internal identity processes during study abroad are not uniformly related to all identity dimensions. Reconnection appears to intensify national identification broadly, whereas perceived loss and psychological strain are more strongly associated with defensive and exclusionary forms of identity expression.

Table 2: Identity strain predictors (β with p-values) (N=308)

DV	»I feel more connected to my country now.«	»I feel more uncertain about myself now.«	»Maintaining my national identity is important for my mental health.«	»I feel like I lost more than what I won by moving to Hungary.«
Strong attachment	.415 (<.001)	-.094 (.073)	.184 (.002)	.008 (.893)
Support but criticize	.232 (.001)	-.113 (.067)	-.099 (.155)	.037 (.577)
Rather citizen	.330 (<.001)	-.089 (.120)	.162 (.013)	.037 (.548)
Proud – history	.175 (.012)	-.101 (.096)	.034 (.621)	-.049 (.458)
Proud – developing	.207 (.003)	-.076 (.209)	.175 (.011)	.069 (.290)
Proud – achievements	.181 (.013)	-.047 (.461)	.123 (.086)	-.045 (.512)
Better than most	.266 (<.001)	-.053 (.374)	.152 (.024)	.163 (.012)
Better if everyone like us	.221 (.001)	.016 (.774)	.167 (.009)	.209 (.001)
Support even if wrong	.083 (.203)	.093 (.103)	.172 (.008)	.169 (.006)
Special treatment	.176 (.008)	-.012 (.836)	.181 (.006)	.265 (<.001)
People underestimate	.193 (.005)	.142 (.018)	.080 (.238)	.045 (.492)

Source: own editing with SPSS software

5.3 Intercultural & international orientation predictors

Table 3 presents the effects of intercultural engagement and international orientation variables on post-mobility national identity. In contrast to the identity strain predictors, these variables demonstrate more selective and less systematic associations across dimensions.

Interaction with international peers shows limited direct effects. It is negatively associated with “I get upset if my country is not recognized” ($\beta = -.126$, $p = .036$), suggesting that greater exposure to diverse peers may reduce sensitivity to perceived external disrespect. However, it does not significantly predict most attachment, pride, or superiority-based items.

Perceived increased international orientation (“I feel more international now”) exhibits a more differentiated pattern. It is positively associated with “I support my country but willing to criticize it” ($\beta = .229$, $p < .001$) and pride in national history ($\beta = .175$, $p = .004$), indicating that stronger international self-identification does not necessarily weaken national belonging. Instead, it appears compatible with more reflective and balanced forms of identification. Importantly, this variable does not systematically predict exclusionary nationalism or entitlement-based attitudes.

Table 3: Intercultural & international orientation predictors (β with p-values)

DV	»I often hang out with internationals«	»I feel more international now«	»I often hang out with my own nationality«
Strong attachment	.037 (.469)	-.037 (.472)	.012 (.814)
Support but criticize	.014 (.818)	.229 (<.001)	.014 (.818)
Rather citizen	.005 (.932)	-.036 (.526)	-.021 (.698)
Proud – history	-.004 (.950)	.175 (.004)	-.029 (.618)
Proud – developing	-.008 (.899)	.089 (.136)	.069 (.236)
Proud – achievements	.096 (.125)	.106 (.091)	.097 (.113)
Better than most	-.060 (.308)	.004 (.940)	-.002 (.978)
Better if everyone like us	.005 (.929)	-.083 (.130)	-.028 (.602)
Support even if wrong	-.070 (.214)	-.083 (.139)	.081 (.139)
Special treatment	-.059 (.302)	-.085 (.136)	-.026 (.640)
People underestimate	-.016 (.786)	-.025 (.676)	-.113 (.053)
Upset not recognized	-.126 (.036)	.079 (.185)	-.077 (.192)

Source: own editing with SPSS software

Contact with co-nationals shows no consistent strengthening effect on national identity. Most coefficients are non-significant, with a marginal negative association for “people underestimate my country” ($\beta = -.113$, $p = .053$), suggesting that clustering with one’s own group does not reliably intensify grievance-based attitudes.

Overall, intercultural exposure variables display weaker and more inconsistent effects than identity strain variables. Their influence appears limited to specific attitudinal nuances rather than broad amplification of national identification. This pattern supports the interpretation that relational exposure during study abroad moderates certain defensive reactions but does not independently drive major shifts in national identity strength.

5.4 Host-country & institutional predictors

Table 4 presents the effects of host-country evaluations and institutional satisfaction on post-mobility national identity. Compared to identity strain variables, these contextual predictors show more selective and dimension-specific associations.

Evaluations of the Hungarian government emerge as the most consistent contextual predictor. Positive government evaluations significantly predict strong attachment ($\beta = .133, p = .039$), multiple patriotism indicators (e.g., pride in history, $\beta = .250, p = .001$), and several exclusionary nationalism and collective narcissism items, including “The world would be a better place if everyone was like my country” ($\beta = .209, p = .002$), “I support my country even if it acts wrongly towards others” ($\beta = .182, p = .009$), and “people underestimate us” ($\beta = .259, p < .001$). This suggests that more favorable political evaluations of the host country are associated with stronger national identification overall. Rather than weakening home attachment, positive host-country political perceptions appear linked to intensified national positioning.

In contrast, perceived living standards show no systematic effects across models. All coefficients are non-significant, indicating that economic evaluations of the host context do not meaningfully predict changes in national identity dimensions within this sample.

University satisfaction displays a more nuanced pattern. It significantly predicts pride in national history ($\beta = .231, p = .001$) and “I support my country even if it acts wrongly towards others” ($\beta = .202, p = .002$), but does not consistently influence exclusionary or grievance-based components. These results suggest that institutional experiences may reinforce affective or normative attachment, yet they do not appear to drive entitlement-based identity expressions.

Overall, contextual evaluations demonstrate explanatory relevance but lack the consistency and breadth observed for internal identity strain variables. Political perceptions of the host country show the clearest association with intensified national identification, whereas economic evaluations and institutional satisfaction exhibit limited and dimension-specific effects. This pattern reinforces the broader finding that internal psychological processes play a more central role in identity dynamics during mobility than structural host-country conditions alone.

Table 4: Host-country & institutional predictors (β with p-values) (N=308)

DV	»Hungary has a good government«	»Hungary has good living standards«	University satisfaction (combined score)
Strong attachment	.133 (.039)	-.071 (.253)	.110 (.062)
Support but criticize	.047 (.534)	-.095 (.195)	.115 (.096)
Rather citizen	.027 (.699)	-.019 (.782)	.093 (.144)
Proud – history	.250 (.001)	-.102 (.156)	.231 (.001)
Proud – developing	.152 (.041)	-.093 (.197)	.051 (.454)
Proud – achievements	.074 (.342)	-.112 (.137)	.092 (.195)
Better than most	.157 (.032)	-.015 (.829)	.091 (.172)
Better if everyone like us	.209 (.002)	-.002 (.975)	.080 (.200)
Support even if wrong	.182 (.009)	.017 (.796)	.202 (.002)
Special treatment	.074 (.299)	-.047 (.493)	.104 (.109)
People underestimate	.259 (<.001)	-.020 (.782)	.066 (.328)
Upset not recognized	.224 (.003)	-.039 (.592)	.103 (.132)

Source: own editing with SPSS software

5.5 Political orientation and religiosity predictors

Political orientation exhibited dimension-specific effects rather than broad structural influence (Table 5). Liberal orientation positively predicted critical patriotism (“I support my country but willing to criticize it”) and citizenship commitment, suggesting that liberal respondents were more likely to endorse engaged but reflective forms of national identification. Liberalism also showed positive associations with normative superiority claims and special treatment endorsement, indicating that international orientation does not necessarily preclude strong evaluative identification.

Conservative orientation was significantly associated with unconditional support of the nation and perceptions that the country is underestimated, aligning with more defensive or status-sensitive identity components. However, conservative orientation did not significantly predict basic attachment or pride-based items.

Religiosity demonstrated minimal systematic influence. Its only significant effect was a negative association with universalist superiority claims, while remaining non-significant across attachment, pride, and narcissistic dimensions.

Overall, ideological orientation contributes selectively to evaluative and exclusionary dimensions of national identity, but does not appear to fundamentally structure emotional attachment or pride-based components.

Table 5: Political orientation and religiosity predictors (β with p-values) (N=308)

DV	Religious	Conservative	Liberal
Strong attachment	.074 (.151)	.048 (.358)	.044 (.367)
Support but criticize	.031 (.612)	.021 (.731)	.141 (.014)
Would rather be citizen	.033 (.556)	.069 (.229)	.178 (.001)
Proud of history	.022 (.711)	.037 (.548)	.033 (.553)
Proud of development	-.011 (.853)	-.022 (.715)	.060 (.283)
Proud of achievements	-.033 (.601)	-.064 (.312)	.038 (.522)
Better than most countries	-.039 (.509)	.027 (.654)	.067 (.226)
Better if everyone like my country	-.116 (.036)	.073 (.195)	.123 (.018)
Support even if wrong	-.067 (.232)	.116 (.043)	.077 (.146)
Special treatment	.058 (.307)	.071 (.220)	.123 (.023)
People underestimate my country	-.113 (.053)	.167 (.005)	.042 (.450)
Upset if not recognized	.058 (.330)	-.002 (.977)	.089 (.116)

Source: own editing with SPSS software

Across the twelve models, identity strain variables emerged as the most consistent predictors of post-mobility national identity. Perceived reconnection to the home country broadly amplified attachment, pride, and exclusionary components, while perceived loss and psychological strain were more strongly associated with defensive and entitlement-based attitudes. Intercultural exposure variables showed selective and generally weaker effects, and host-country evaluations were dimension-specific, with political perceptions demonstrating the clearest contextual influence. Political orientation contributed selectively to evaluative and exclusionary dimensions, whereas religiosity showed minimal and inconsistent effects. Overall, internal identity processes displayed greater explanatory strength than relational, ideological, or structural factors.

6 Conclusions

This study examined the determinants of post-mobility national identity among international students, focusing on psychological strain, intercultural engagement, and host-country evaluations. By analyzing twelve identity items across four conceptual dimensions, the findings provide a differentiated view of how identity processes unfold during study abroad.

H1. Higher levels of identity strain are associated with stronger post-mobility national identification.

This hypothesis was largely supported. Identity strain variables, particularly perceived increased connectedness to the home country and national identity-related psychological strain, demonstrated consistent and significant associations across multiple identity dimensions. These effects were especially pronounced for exclusionary nationalism and collective narcissism components. The results suggest that identity strain does not weaken national identification but rather intensifies it, often in more rigid or defensive forms.

H2. Greater intercultural engagement and international orientation are associated with lower levels of exclusionary national identity.

This hypothesis received only partial support. While interaction with international peers was negatively associated with sensitivity to perceived national disrespect, intercultural engagement did not systematically reduce exclusionary attitudes across models. In some cases, increased international orientation coexisted with stable or even reinforced national attachment. These findings indicate that intercultural exposure alone does not automatically translate into weaker exclusionary identification.

H3. Evaluations of host-country political, economic, and social conditions are associated with post-mobility national identity.

This hypothesis was partially supported. Political evaluations of the host country were significantly associated with several national identity components, particularly attachment and nationalism-related items. However, economic evaluations (e.g., living standards) showed no consistent effects. Institutional satisfaction

demonstrated selective associations but did not systematically predict exclusionary identity forms. Thus, contextual perceptions matter, but their influence is dimension-specific and weaker than psychological factors.

H4. Psychological factors related to identity strain account for greater variance in national identity than contextual and institutional factors.

This hypothesis was supported. Across models, identity strain variables exhibited more consistent and theoretically coherent effects than intercultural exposure or contextual evaluations. The strongest explanatory power emerged in models where psychological predictors were central, indicating that internal identity processes play a more decisive role in shaping post-mobility national identification than structural or relational conditions alone.

Political orientation demonstrated selective influence, particularly for evaluative and exclusionary components. Conservative orientation was associated with unconditional support and perceived national under-recognition, whereas liberal orientation predicted both critical patriotism and certain normative superiority claims. Religiosity showed minimal and inconsistent effects. These findings indicate that pre-existing ideological dispositions continue to structure identity expression during mobility but do not override the central role of psychological strain.

Taken together, the findings suggest that national identity change during study abroad is driven primarily by internal psychological mechanisms rather than by host-country characteristics or mere exposure to diversity. Study abroad does not inherently dilute national identity. Instead, identity strain and perceived reconnection may intensify identification, particularly in defensive and exclusionary forms.

These results challenge simplified assumptions that international mobility naturally fosters cosmopolitan detachment. Instead, identity processes during mobility appear complex and contingent, with internal strain functioning as a key driver of identity reinforcement.

6.1 Limitations of the study

This study is subject to limitations inherent in questionnaire-based, self-report research. Responses may be influenced by social desirability bias, recall bias, and individual interpretation of survey items, all of which can shape how attitudes and experiences are reported. The cross-sectional design captures perceptions at a single point in time, limiting causal interpretation. Although these factors may introduce some measurement error, the use of multiple indicators and consistent patterns across models supports the robustness of the findings.

7 Summary

This study investigated how international mobility shapes national identity among students studying abroad. Using twelve regression models across four identity dimensions, the analysis demonstrated that post-mobility national identification is primarily structured by internal psychological dynamics rather than by contextual exposure alone.

Identity strain and perceived reconnection to the home country emerged as the most consistent predictors of national attachment and evaluative components. Intercultural engagement and host-country evaluations showed dimension-specific effects, while political orientation selectively influenced exclusionary and normative expressions of identity. Religiosity played a limited role.

Overall, the findings suggest that study abroad does not automatically weaken national identity. Instead, mobility can intensify or reshape identification through psychologically mediated processes that interact with ideological predispositions.

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EMPOWERING SUSTAINABLE GOVERNANCE: THE ROLE OF GREEN PUBLIC PROCUREMENT AND CERTIFICATIONS IN HUNGARY

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Agenda 2030 aim is to create a global framework for a sustainable economy in the EU. Green public procurements play a key role in this transformation in three aspects: (1) supports sustainable governance and management by embedding ESG principles into the decision-making process, also (2) it provides significant demand for environmental-friendly products and services and with that, motivation for green innovations. Thirdly, (3) completed procurements contribute to better environmental conditions improving quality of life. Green certifications support the process by providing credible, standardized proof that products and services meet the sustainability criteria. The aim of the chapter is to analyse how green public procurements have changed in Hungary in recent years and where the emphasis has shifted. The primary and secondary analyses are based on two sources from the Public Procurement Authority's database. In addition to the development of the proportion of green public procurements, the study focuses on the importance of environmental certification as an expectation for bidders.

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1 Relevance of green public procurements in Hungary

AGENDA 2030 is a global action plan adopted by the UN in 2015, which defined 17 Sustainable Development Goals (SDGs), including climate protection, sustainable economy, resource efficiency, and social justice (UN, 2015). Focusing on the environmental protection elements of the Agenda, the European Green Deal sets out a comprehensive plan to achieve a net greenhouse gas reduction of at least 55% by 2030 for the European Union compared to 1990 levels, and a more ambitious goal: climate neutrality for 2050. (European Commission, n.d.-b)

Green public procurement (GPP) is public procurement in which the contracting authority takes environmental protection into account at every stage of the procurement process and encourages the spread of environmentally friendly technologies and the production of environmentally friendly products by seeking and prioritizing solutions that have the lowest possible impact throughout the life cycle (European Commission, 2008). With that, public authorities can lower their negative environmental effects (Pouikli, 2021, Eisenger et al. 2022), while with their significant and stable demand they can motivate entrepreneurs to improve their environmental performance and they can promote the importance of green transition (Lundberg et al., 2015). Luo and Zhao (2026) also highlight the advantages of GPP for bidders in the form of contribution to the green reputation and in easing the financial pressure on companies.

2 Development of green public procurements in Hungary

In line with the EU Agenda, Hungary's Green Public Procurement Strategy for 2022-2027 aims to achieve 30% of public procurement by 2027 (Hungarian Government, 2022). Based on the provisions of Act CXLIII of 2015 on Public Procurement (Kbt.), environmental considerations can be applied in public procurement procedures based on regulations that can be classified into four categories, in accordance with EU law, which are the following: selection criteria (exclusion or suitability requirements), award criteria (evaluation criteria), specifications of the public procurement specifications, and clauses relating to the performance of the contract. (Paksi, 2020)

According to the latest available data on the Hungarian Central Statistical Office webpage, 15.3% of public procurement procedures conducted under the national procedure included environmental considerations in 2023. Both the number and value of green public procurements were in a rise in 2023, following a quite volatile period between 2016-2022. (HCSO, 2024)

Table 1: Number and value of green public procurement in Hungary (2016-2023)

Year	Number of green public procurements	Value of green public procurements in billion HUF / in million EUR
2016	613	43,4 / 138,7
2017	831	102,9 / 332,8
2018	1080	136,8 / 429,0
2019	916	119,8 / 368,3
2020	474	68,5 / 195,1
2021	501	63,7 / 177,6
2022	470	61,7 / 157,7
2023	695	80,8 / 211,7

Source: Hungarian Central Statistical Office, <https://ksh.hu/kiadvanyok/fenntarthato-fejlodes-indikatorai/2024/4-7-sdg-8>, EUR calculated based on the average annual exchange rate of MNB (own edition)

Contracting authorities continued to pay the most attention to environmental aspects in construction projects: more than 20% of the number of construction projects conducted and, in their value) (HCSO 2024).

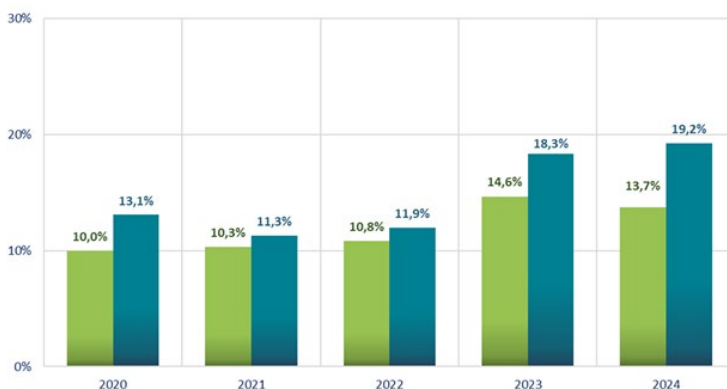


Figure 1: Green public procurement in proportion of number (light green) and value (dark green) of all procurement (in national procedure) in Hungary between 2020-2024

Source: Public Procurement Authority, 2025, p.24

Within the public procurement procedures having environmental aspects in 2021, green conditions were mentioned as contracting criteria in 52,7% of the tenders, in 47,3% it was an evaluation aspect and in 32,2 % of the cases it was a technical parameter (Hungarian Government, 2022). The 2024 Report on Public Procurement shows the increasing value proportion of green public procurements in national procedures, while the proportion of the numbers of these procurements is slightly decreased from 2023 to 2024.

3 Green certifications – their roles and their forms

Third party, independent environmental certifications play a significant role in helping transition to a green economy. Besides summarizing relevant features of a given product into one communication element, they promote the purity and fairness of competition. It is an important feature till the growing demand for environmentally friendly solutions have increased the probability of greenwashing activities on consumer markets (Santos et al., 2024). However, Lou and Zhou (2026) found evidence that GPP significantly constrains corporate ESG greenwashing, and this effect was more visible for companies working in highly competitive industries in the maturity stage.

Green labels play a significant role in decreasing greenwashing. Greenwashing is the act of misleading consumers about the environmental practices of an organization (firm-level) or the environmental benefits of a product or service (product/ service-level) (de Freitas Netto et al., 2020). Greenwashing is extremely harmful as it leads to a non-optimal resource allocation and puts truly green companies at a disadvantage. From this perspective, using false labels can be categorized as product/service level greenwashing. They also differentiate claim and executional greenwashing types. Claim greenwashing occurs when an explicit textual environmental claim (e.g. “CO₂-neutral”, “derived from sustainable forestry”) is in fact false or exaggerated, while executional greenwashing can be detected by using implicit visual/colour elements (e.g. green images, leaves, nature images) that create an impression but do not reflect the actual environmental performance (de Freitas Netto et al., 2020). Fake, not independent, not official green seals can mislead buyers who would like to enforce green aspects in their buying behaviour; therefore, it is important to educate consumers and businesses about the meaning and conditions

of different green labels. The higher the need for this compact and reliable information the more companies will strive to obtain the certificate.

In the EU there are voluntary GPP criteria for certain product categories like computers, monitors and smartphones; data-centres, furniture, food catering services, indoor cleaning services, electricity, imaging equipment, consumables and print service; office building design, construction and management, public road design, construction and maintenance and public space maintenance, road lightning and transport and textile products.(EC, Green Forum) Typically, Type I ecolabels are required to meet the criteria of a GPP. The common features of these environmental-friendly certifications are that they are based on multiple criteria and a life-cycle analysis, and an independent third-party organization awards it. Practically, they are the EU Ecolabel, the Nordic Swan, or the Blue Angel.

The Hungarian National Eco-label is the Green Cedar. The Green Cedar is a competitive tool that increases turnover, “which allows the manufacturer, distributor and service provider to earn more income and in public procurement, these goods are suitable for most Western distributors” and can also “take advantage of the discounts provided by law; (discounts and exemptions provided by the product fee law; or the market opportunity provided by green public procurement)” (Herman Otto Institute Ltd, n.d.). This would be an important motivator for companies to improve their market competitiveness by meeting the requirements of the label and communicating their achievements. Compliance with the criteria also results in multi-level cost-savings by resource saving and waste reduction.

The other important certification is the EU Ecolabel which is also an official and voluntary label for proving the compliance with green requirements. (European Commission, n.d.-d) EU Ecolabel is quite successful as nowadays more than 109.000 products can use its certification all over Europe. EU ecolabel has been awarded in highest number to paint and varnishes, paper products, cleaning up and clothing and textile categories so far. However, in the past 6 months, the most increasing product groups awarded by the label belong to tourist accommodation services, indoor cleaning services, furniture, and lubricant categories. (European Commission, n.d.-c)

According to the EC Ecolabel Facts and Figures site, in Hungary there are 104 products certified with EU Ecolabel (Sept 2025), which seems relatively much compared to the neighbouring Slovakia, where the number is just 15 products, but seems very low, if we compare it to Austria, where there are 1240 products certified by EU Ecolabel. And there is even more room for development as in Spain recently 16280 products have the right to use the EU Ecolabel on them. (European Commission, n.d.-c).

Table 2: Recent users of official eco-labels in Hungary

	National Environmental-friendly Product certification	EU Ecolabel
Logo		
Number of certified Hungarian companies in January, 2026	9 companies ²	7 companies ²
Number of products	13 product categories ²	104 product ¹

Sources: ¹European Commission (Sept 2025 data) c); ²<https://www.hermanottointezet.hu/nemzeti-okocimkerol> (own edition, own compilation)

This significant difference between the number of certified products is explained at least partly with the voluntary or mandatory implementation of GPP directives by member states in the EU. Spain decided to foster the green transition by being more focused on green aspects of public procurements with stricter expectation in the procurement process (Rossell, 2023). Also, Italy took big steps as “Public procurement in Italy allows Type 1 ecolabels to be used as the only means of conformity for sustainability criteria.” This has motivated companies to follow ISO 14024 and being awarded by the EU Ecolabel (European Commission, n.d.-d)

4 Expectation of green certifications in green public procurements

In the period 2020-2024 in Hungary, most green aspects were prescribed by contracting authorities in construction projects and applied in procurements financed from EU funds (Hubai, 2025). In 2024, 900 green public procurement

procedures were conducted under national procedures and the proportion of public procurement contracts having green aspects was 13.7%. (Public Procurement Authority, 2025)

The slow increase in the proportion of green public procurement in the last few years shows that, despite the different available aids and training, and presumably without a legal obligation, green public procurement cannot be expected to spread more widely. Therefore, there are grand expectations toward the new Government Decree 235/2024. (VIII. 8.) on environmental protection requirements in public procurement, which sets out mandatory environmental features for various procurements. This new legislation could bring significant and positive changes to this area in the short term. The scope of the Government Decree covers 11 product groups, two services and a part of construction projects. Except for existing buildings and public roads, the regulations must be applied in both national and EU procedural rules (Hubai, 2025)

4.1 Research method

Based on the Decree, products that comply with the technical specifications and have an ISO type I (environmentally friendly product) or an international eco-label (e.g. EU Ecolabel), as well as equivalent certificates specified in Sections 59-60 of the Public Procurement Act, are ‘environmentally friendly products’. The product offered is equivalent if it meets the EU Ecolabel qualification requirements. Therefore, in our study, we used content analysis method as a primary research method to show how intense the usage of green aspects in public procurements is and how detailed the related descriptions in the notices are - especially focusing on the expectations of eco-labels. For that, the online database of the Hungarian Public Procurement Authority was used, and we have collected notices from 1st January 2025 till 31 December 2025. We used the following terms, to find those notices which fit to our study: “environmentally friendly”, “environmental-friendly certification”, “eco-label”, “EU ecolabel”, “Environmentally Friendly Product label” (the Green Cedar) and “ISO 14024”. The difficulty of this search was the unique feature of the Hungarian language since inflections and suffixes are attached to the word stem; therefore, expressions often appear in inflected and suffixed forms in the text. The result of this search is shown in Table 3.

4.2 Research results

Numbers in the table reflect the legislation changes: significantly higher number of public procurements mentioned environmental-related conditions in their notices, and half of them required eco-label-certified products or services in 2025. Comparing it to 2024, it is remarkable that environmental certifications now clearly and inescapably demonstrated as a need for public institutions.

Table 3: Mentioning eco-related terms in Green Public Procurement notices in 2024 and 2025 in Hungary

	Number of green public procurements where notice mentions:	
	2024	2025
Environmental-friendly	27	44
Environmental-friendly product	2	24
Type I. ecolabel	2	23
EU ecolabel	0	3
Hungarian eco-label (green cedar)	1	23
Eco-label	5	9
ISO 14024 standard	0	1

Source: www.kozbeszerzes.hu/adatbazis (own compilation) (database used with the given terms, search 01.01-31.12. 2025 and 01.01-31.12, 2024)

Almost half of the tenders using the expression „Environmentally friendly” was connected to buying cleaning products and services and they all mentioned at least one-type of ecolabel needed in the notice. The standard text in almost every public procurement notice was the following:

"During the performance of the contract, in accordance with point a) of Section 5 of Government Decree 235/2024. (VIII.8.), at least 70% of all cleaning products to be used for the performance of the tasks related to the contract must continuously comply with criteria 1 (toxic effect on aquatic organisms) and 4 (excluded and restricted substances) of the Annex to Commission Decision 2017/1217/EU establishing the criteria for the award of the **EU Ecolabel** for cleaning products for hard surfaces or with the criteria of the **Environmentally Friendly Product Label** with the same content, and at least 50% of all cleaning products made of textile material to be used for the performance of the tasks related to the contract must be

made of microfiber material, and at least 70% of sanitary and household paper products and household hygiene papers must have a **Type I ecolabel.**" (own highlight) (17731/2025 PP).

Type I eco-labels have often been required in procedures. However, there would be a significant need for a list of Type I eco-labels, as contracting authorities find it difficult to decide whether a given eco-label – especially if it is less well-known – meets the definition set out in Section 2, Section 1 of the Government Decree (Hubai, 2025)

In some cases, the description uses the term ‘environmentally friendly’ in general term without specifying under what conditions a particular solution can be considered environmentally friendly. “Road salt should not be used in the immediate vicinity of green areas; the materials and methods used here must be environmentally friendly and must not harm the environment.” (13289/2025 PP) In other cases there are added regulations needed to be considered by the bidders: “...environmentally friendly anti-slip and weed control materials may be used. The anti-slip material must follow the provisions of the Balaton-Felvidéki National Park Directorate's Resolution No. 3761-2/2015, Section 19 of Government Decree No. 282/2024 (IX. 30.), and the environmental protection regulations applicable to local conditions.” (19398/2025 PP)

The other extreme is the example of Kazincbarcika School District Centre's Procurement notice in which the exact product types are mentioned with EU Ecolabel (“liquid soap, refill 5 l Lucart Hand Care Soap hand protection liquid soap (EU ECOLABEL); disinfectant hand cleaning liquid soap, 5 l Sure Antibac liquid hand disinfectant soap, environmentally friendly (EU ECOLABEL); hand cleaning paste, 0.4 kg Kroll Octima Ecolabel (EU ECOLABEL)” while other products are also on the list with not-at-all environmentally friendly features like “stain remover, 1 l Vanish Oxi Action Stain Remover and Whitening Gel Concentrate; fabric softener, 5 l Coccolino Professional Pure Concentrate; air freshener, 0.3 l Ambi Pur Spring Awakening Air Freshener; hand-held carpet and upholstery cleaner, 0.5 l Vanish Gold hand-held carpet and upholstery shampoo.” (17503/2025 PP) This list clearly shows purchases that are not well thought out and have not changed their perspective strategically.

Only two tenders focused on green aspects in other than cleaning products or services: one related to IT equipment “the imaging equipment must have a Type I eco-label. c) a document certifying compliance with the prescribed environmental protection (ENERGY STAR or Type I eco-label) requirement” (18536/2025 PP); and the other was about hygiene paper products for Central Buda School District Centre (paper towels and toilet papers) (3097/2025 PP). The only notice mentioning ISO 14024 standard was a furniture procurement tender for a nursing home.

5 Conclusion and discussion

The relatively low level of green public procurements, the voluntary nature of green public procurement and the low knowledge of the official green certifications among consumers were all responsible for the low incidence rate of expecting EU Ecolabel or Hungarian Green Cedar as a criterion for bidders in public procurement procedures. Under the new regulations, there will be greater pressure on entrepreneurs to have their products certified by the EU or national eco-labels to successfully bid for green public procurement.

In the analysed cases, majority of the contracting authorities specified the green requirements as part of the technical specifications, but contract performance conditions were also often prescribed. The criteria included in the Government Decree and other environmental requirements also appeared as evaluation criteria in the calls for tenders, although not very often.

As the number of Hungarian products awarded by the Hungarian seal or the EU eco-label is relatively low, the stricter conditions of green public procurements will lead Hungarian companies to be least likely successful on green public procurements if they do not have the proper certificates. It may create a boom in requirements for certification processes. Those companies who think about a larger market on the long run, should focus on being awarded by the EU Ecolabel. However, smaller Hungarian SMEs can still find competitive advantage in communicating the Hungarian Green Cedar in relation to their products.

Not surprisingly, the biggest cost of being an environmentally friendly producer or service provider is the investment and effort needed. However, communicating it in a reliable and trustful way also worth to pay for. In connection with the EU Ecolabel,

the legislator made significant differentiation in the fees, considering the interests of smaller businesses. For micro entrepreneurs, the fees for whole certification procedure count in general one third-fourth of the fee paid by a big company. The certification is valid for 3-5 years. Unfortunately, similar generous distinctions are not available for the Hungarian certification related to the application fee or the annual fee – although the latter is proportional to the revenue.

It has only been the first year since the tightening of regulations, so far-reaching conclusions cannot be drawn from the data. Of course, it is necessary for public procurement professionals who apply the rules to gain experience of the difficulties of adapting to the new conditions, both from the applicants and tenderers sides. The Government Decree stipulates that the contracting authority is obliged to specify in the public procurement documents the control method of compliance with the requirements. So, it is not enough for companies to be environmentally friendly; they must also prove this in a credible manner. It is more convenient for clients to check the existence of a certificate than to conduct a full review of company processes to decide compliance. Therefore, we can expect that more companies will recognize the long-term benefits of obtaining official, third-party green certifications.

Table 4: Comparison of fees for the application processes for EU Ecolabel and Hungarian Environmentally Friendly Product certification for a micro enterprise (in HUF and in €)

	Fee structure for micro enterprise	
	EU Ecolabel ¹	Hungarian Environmentally Friendly Eco-label ²
Application fee	HUF 80.000 (220 €) +VAT	HUF 150.000 (413 €) +VAT
Discounts from application fee	EMAS: 30% ISO 14001: 15%	EMAS: 30% ISO 14001: 15%
Annual fee	HUF 90.000 (248 €) +VAT	up to HUF 1 bn revenue it is HUF 120.000 (EUR 330 €) +VAT
Examination fee	HUF 20.000 (55 €) +VAT	HUF 20.000 (55 €) +VAT

Sources: ¹<https://www.hermanottointezet.hu/az-eu-okocimkerol/>; ² <https://www.hermanottointezet.hu/vedjegy-megszerzese> (own edition, own compilation) - prizes in EUR added by the authors

The remarkably similar formulation of green requirements - especially in connection with cleaning services - shows that in majority of cases the simplest environmental conditions were specified in the GPP. This result is in line with Hubai's experience (Hubai, 2025).

Type 1 eco-labels help to make the competition fairer. Chen et al., (2023) highlights the role of rewarding or punishing government policy combinations to decrease greenwashing in public procurements. Factors which cause limited rationality in the process are information asymmetry, economic interests and social roles. They emphasize the role of setting red lines and creating a system where the potential benefits of government reward and earned reputation overcome the benefits of using greenwashing practices. (Chen et al., 2023)

Limitations of these study results arise on one hand, from the fact that a relatively short time has passed since the introduction of the new regulation. On the other hand, keyword search focuses only on the existence of an expression but not on its importance in decision making processes. Tender documents can focus only on what bidders want to receive, what are their expectations, but the reality is, that the implementation of the project may result in a very different outcome. In the future, the study should go further in analyzing tenders also based on technical specifications and on performance clauses. Moreover, examining the implementation processes can add an additional aspect to the research on green public procurements.

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ENVIRONMENTALLY CONSCIOUS PRINCIPLES IN EVENT MANAGEMENT

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From a corporate perspective, events are not only costly undertakings, but also pose substantial challenges in complying with environmental regulations and standards. In recent years, environmental, social and governance (ESG) requirements have introduced conditions whose fulfilment often entails significant financial and resource-related burdens. This research examines the event types organised by companies, such as exhibitions, conferences and internal corporate events, through the lens of environmental considerations. In a literature review an international overview of sustainable event management is assembled as a background for deeper understanding the general issues of the industry. As primary research, we conducted semi-structured interviews with eight experts in 2024/25, through which we obtained up-to-date insights into the sustainability efforts and challenges faced by Hungarian companies in the context of event organisation. The sampling strategy applied in this study followed a combination of purposive, expert, and maximum variation sampling. The study contributes to the emerging literature on green event management by outlining the organisational, regulatory and cultural factors shaping adoption. The paper concludes with managerial implications and recommendations for enhancing supplier capacity and reducing cost barriers, while highlighting directions for further research on recycling systems and environmental education in event contexts.

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1 Introduction

The relevance of this study lies in the fact that, in recent years, companies have been required not merely to articulate a straightforward objective for their events, but also to adopt an educational role by raising participants' awareness of the importance of environmental protection. The purpose of an event extends beyond entertainment; organizations have an obligation to ensure that they do not deplete their resources in a self-serving manner, but instead consider opportunities to create a positive impact on society and the environment. Depending on the type of event, companies have a wide range of possibilities for showcasing their sustainability commitments. These will be examined in detail in this work.

Throughout our research, we engaged with Hungarian professionals who are deeply committed to advancing sustainability and willingly shared their international expertise. In these discussions, they outlined the challenges companies face in complying with regulations, implementing environmental protection measures, and managing the associated costs.

By synthesising these insights, together with the findings presented in existing guidelines, publications, and scholarly articles, our aim is to provide guidance and practical support for companies in organising successful green events, thereby setting a positive example for their employees and partners. The paper addresses organisational steps, supplier preparedness, and cost implications.

2 Literature review

The focus of our analysis is corporate events in Hungary, whose objectives must consistently align with the company's overarching strategy and key messages (Dér, 2013). For companies whose operations generate substantial pollution, it is essential during networking occasions to highlight how they compensate for their environmental impacts, what sustainability commitments they uphold, and what concrete actions they take to protect their surroundings (Jones, 2017).

Sustainability now requires conscious action because the impacts of different actors are deeply interconnected. Yet corporate and consumer responsibilities are still often treated separately, with companies focusing on CSR and individuals expected to

practice responsible consumption. Events offer a powerful platform to bridge this gap by bringing these actors together and fostering shared, practical sustainability commitments (Szigeti et al., 2023).

The event industry, while contributing significant social, cultural, educational and economic value to global tourism, simultaneously poses environmental risks by generating substantial waste through the excessive use of materials before, during and after events. According to Wang: “altering the event operations to be green is becoming a necessity to improve competitiveness in the whole market and provide a healthy earth for the next generation” (Wang, 2017).

According to data from the European Environmental Agency (EEA), the global population is projected to exceed 10 billion by 2060, and the expanding economy will require resources equivalent to twice the Earth’s current capacity. Energy consumption is expected to increase by 60%, and water use by 55%. The zero-pollution ambition aims to reduce pollution by 2050 to levels that no longer pose risks to human health or natural ecosystems (European Green Deal, 2021). However, the EEA’s most recent Zero Pollution Monitoring and Outlook 2025 report indicates that current progress falls far short of these targets. Municipal waste was intended to be reduced by 50% by 2030, yet even selective waste collection is insufficient to bring the EU closer to this goal. Without ambitious measures, the volume of waste, growing in parallel with the EU’s GDP, will not meet the target either (European Environment Agency., 2025). From this, we conclude that our task is not limited to reducing waste generation; it also requires the deliberate and well-designed implementation of recycling practices.

According to other studies, the composting, food donation programs, and waste audits are excellent waste reduction methods (Surbhi & Bose, 2025).

Whether it is a company executive, a conference organiser, or the owner of an exhibition venue, the overarching aim is to design an event that reflects the organisation’s strategic direction, to define appropriate success indicators, and thereby contribute to improving corporate performance. At the 2024 “Rendezvény Restart” event, speakers unanimously emphasised that sustainability requirements must be initiated at the leadership level; however, without adequate education and awareness-raising, implementation will inevitably fall short. As Lőrincz sums up in

his study: “both the organizers and the visitors can, and also have to, take their share in the efforts towards sustainability” (Lőrincz et al., 2022)

Focusing solely on making a single event more sustainable risks overlooking the broader potential of events to support sustainable development. Beyond reducing their own environmental footprint, events can function as platforms that educate, motivate, and expose participants to experiences that may encourage the adoption of more sustainable lifestyles (Mair & Smith, 2021).

ISO 20121 is an international management system standard specifically developed for the events industry, providing a structured framework for integrating sustainability into all stages of event planning and delivery. The standard emphasises continuous improvement, stakeholder engagement, and the identification of social, environmental, and economic impacts across the entire event lifecycle. Rather than prescribing specific performance criteria, ISO 20121 focuses on establishing processes that enable organisations to set objectives, monitor progress, and implement corrective actions. It was first introduced in the context of the London 2012 Olympic Games, which served as a major catalyst for its global adoption (ISO 20121:2024, 2024). Today, ISO 20121 is widely recognised as the most comprehensive sustainability framework for event organisers, venues, and suppliers. The involvement of professionals who are familiar with environmental regulations and the ISO 20121 standard significantly facilitates proper implementation (Jones, 2017). However, due to the high cost of certification, in Hungary only a handful of companies currently possess this accreditation.

The professional contributors to events are the specialised suppliers whose expertise and experience provide a foundation for articulating and operationalising environmental objectives. In the Hungarian capital, the Budapest Congress Center and Hungexpo currently offer the most extensive event infrastructure. When selecting a venue, it is advisable to consider its accessibility by public transport and whether it provides charging stations for electric cars or scooters (Jones, 2025).

According to a Hungarian study conducted in 2023, climate anxiety among Generation Z is significantly stronger than among individuals over the age of 30. Interestingly, within Generation Y, it is the 45–54-year-old members of Generation X who express greater concern for their children’s future (Szeberényi, 2024).

These findings should be considered when formulating event messages targeted at specific audience segments. Younger participants tend to have a stronger demand for factual information and concrete solutions. It is reasonable to expect Generation Z to use selective waste-collection points correctly, as they have largely been socialised into such practices. However, due to their age, they also require the most accurate and accessible information. Providing this guidance is the responsibility of event organisers.

A study examining 350 large corporations demonstrates that financial performance improves following the implementation of ESG practices (Bruna et al., 2022). This finding is not surprising, given that the demand for sustainability reporting originally emerged from the financial sector.

As highlighted by András Szeberényi (2024, p. 131), although individuals consider climate-related actions important, everyday challenges often leave them with insufficient capacity to translate these concerns into concrete behaviour. He also points out that material prosperity does not necessarily foster commitment to environmental protection, as “the intensive influence of consumer society exacerbates the wasteful use of resources.” This observation was echoed by several interviewees during the primary research.

In the implementation of sustainable corporate events, resource optimization is not only an environmental imperative but also a key factor in economic efficiency and corporate reputation.

Overall, the literature highlights that the adoption of sustainable event management practices is shaped by organisational strategy, supplier capacity, and participant attitudes. International studies and professional standards discuss these dimensions mainly as related but separate requirements, including strategic commitment and stakeholder management under ISO 20121, the educational role of events (Mair & Smith, 2021), and the behavioural expectations placed on participants (Wang, 2017). However, empirical evidence on how these factors interact in the Hungarian corporate event context remains limited, especially in studies that consider both client-side and supplier-side perspectives. This study addresses that gap by examining how organisational commitment, market readiness, and cost-related

constraints shape the practical implementation of environmentally conscious corporate events in Hungary.

3 Methodology

In addition to the literature review, the core foundation of this empirical investigation is a series of semi-structured expert interviews with professionals who have long-standing experience in the event industry and who, through direct client interactions, can provide an accurate picture of both Hungarian and international corporate practice. The interview guide followed the same structure in each case and was organised around the three research questions, with follow-up prompts used to clarify concrete practices, implementation barriers, and cost-related considerations.

The sampling strategy applied in this study followed a combination of purposive, expert, and maximum variation sampling. The eight interview participants included event managers, an event director, sustainability specialists, and leaders from hospitality and exhibition stand construction. All interviewees had between 10 and 20 years of professional experience in the Hungarian and international event industry, ensuring a high level of expertise and practical insight. Maximum variation sampling was important because it enabled comparison across different parts of the event ecosystem. During the analysis, credibility was supported through iterative questioning and constant comparison across the interview materials, while dependability was strengthened by the consistent interview guide and the documentation of analytical decisions.

This study is guided by three research questions: (1) What steps must companies take to organise environmentally conscious events? (2) How well prepared are Hungarian suppliers and agencies to support corporate environmental ambitions? (3) Do sustainable events necessarily involve additional costs? These questions informed the interview guide, the analytical procedure, and the structure of the results section.

The analysis of the interviews aims to identify and synthesise good practices that can be adopted by other enterprises to enhance their environmental performance and advance sustainability. It also enables a structured comparison between client-side and supplier-side interpretations of the same implementation problems.

4 Results

The results are organised according to the three research questions set out in Section 3.

Q1: What steps must companies take to organise their events in an environmentally conscious manner?

Based on the interviews, multinational companies typically have global strategies that already incorporate sustainability actions. According to the interviewed sustainability specialist, "among Hungarian SMEs, such initiatives usually begin only when senior management explicitly supports environmental measures". Corporate-side respondents emphasised internal training and the early definition of sustainability criteria, while supplier-side respondents stressed the need for early briefing and realistic expectations toward venues and service providers. When financial resources are allocated, the training of internal staff becomes essential to ensure that the organisation can identify and follow the appropriate direction. Moreover, planning a green event requires early engagement with well-prepared partners. Table 1 summarises the options identified in the interviews to support the implementation of environmental actions in line with the company's level of sustainability awareness and commitment.

Q2: How well prepared are suppliers and agencies in Hungary to support companies' environmental ambitions?

With a few exceptions, only a small proportion of venues and partners in Hungary are equipped to offer environmentally conscious options. As one large-venue manager explained, "venues can improve their sustainability performance only through significant financial investment, the cost of which they are often compelled to pass on to their clients". Supplier-side respondents consistently identified infrastructure, waste-sorting capacity, and the limited availability of alternative materials as the main barriers, while corporate-side respondents pointed to the uneven market availability of credible green options. This suggests that supplier readiness is constrained not only by willingness, but also by the current material and infrastructural conditions of the market.

Q3: Can sustainable events only be implemented at additional cost?

Green events generally require extra expenditure, and although there are opportunities to reduce costs in certain areas, most additional services remain expensive at present. As two event managers suggested, "It is advisable to prepare two budgets: one for a traditional event and one for a green event." The interviews also showed that cost effects differ by type of measure: reducing printed materials, unnecessary giveaways, or over-ordering can lower expenditure, whereas audited catering, alternative materials, and more complex logistics usually increase budgets. Well-designed environmental measures can therefore reallocate costs rather than simply raise them, but large-scale events still tend to require higher spending and additional labour.

5 Discussion and conclusion

Table 1: Environmental actions undertaken by companies based on their level of commitment

Area	Basic actions	Advanced Sustainability Measures
Printing / Digitalisation	Digitalising printed informational materials Printing or renting stand walls Use of digital displays QR-code-based promotional materials	Use of recycled paper Reusing exhibition stands Energy-efficient operation of LED walls
Giveaways	Bamboo or recycled-material items	Experience-based gifts, vouchers Donations to foundations
Catering	Replacing single-use items with porcelain and metal cutlery Glass-bottled drinks or filtered water instead of PET bottles Seasonal menus	Minimal meat content Local suppliers Monitoring kitchen packaging and energy use
Transportation	Organised shuttle buses	Venue located near public transport or rail network Car-sharing services
Waste	Selective waste collection (if provided by the venue)	Waste sorting with external partners Waste reduction through planning Food bank donations
Energy Use	Measures taken primarily for business efficiency	Conscious management and measurement of electricity and water consumption

Source: Author's compilation, 2025

Table 1 summarises the interview-based measures and distinguishes basic from more advanced sustainability actions.

The findings of this research reveal a clear gap between the sustainability ambitions articulated in international guidelines and the practical realities of the Hungarian event industry. Across the interviews, three connected themes emerged: leadership commitment within client organisations, supplier and venue readiness, and the limited measurement of environmental performance. While multinational companies often operate within established global frameworks, smaller domestic firms tend to rely on ad-hoc initiatives driven by individual managerial commitment. According to some interviewees, clients do not yet demand such services to a degree that would justify agencies investing more energy in further training. This indicates that the main drivers identified in the literature do not operate evenly in Hungary: strategic intent may already be present, but market demand and operational capacity often lag behind.

The results also highlight structural limitations within the supplier ecosystem. Even at the largest venues, selective waste management remains a major challenge, suggesting that infrastructural constraints significantly hinder the implementation of higher-level sustainability measures. This aligns with international studies emphasising that environmental performance in events is strongly dependent on venue capabilities and supplier readiness. The lack of affordable, degradable stand-construction materials and the continued reliance on single-use catering equipment further illustrate how technological and market gaps restrict progress. Supplier-side respondents described these limits primarily as operational constraints, whereas client-side respondents experienced them mainly as a shortage of credible options on the market. Most interviewees noted that many Western European countries, affluent Arab states, and the United States often overlook circular-economy principles, as adhering to them would require event organisers to reduce the use of extravagant booth elements and marketing materials, practices that are typically prioritised to maximise visitor comfort and create a strong impression.

At the same time, the interviews point to areas where meaningful improvements are already emerging. Companies in Hungary increasingly replace single-use items with reusable alternatives and reduce PET bottle usage, demonstrating that low-cost, high-impact interventions are feasible even within current constraints. These

findings support the argument that sustainable event management does not necessarily entail higher overall costs; rather, savings from reduced printing, more accurate ordering, and the elimination of unnecessary giveaways can be redirected toward impactful environmental measures.

However, the absence of carbon-footprint calculation systems remains a critical bottleneck. Without reliable measurement tools, companies cannot evaluate the effectiveness of their actions or communicate their achievements transparently, both of which are essential components of ESG-driven corporate communication.

Overall, the study demonstrates that while the foundations of environmentally conscious event management are present in Hungary, the transition toward advanced sustainability practices requires stronger client demand, improved supplier capacity, and broader access to technological solutions. Given the exploratory design and the small expert sample, these findings should be read as analytical insights rather than statistically representative evidence. Future research should focus on recycling systems for event-generated waste, environmental education, and measurement tools that make environmental outcomes comparable across events. These dimensions are likely to determine how effectively the industry can move beyond basic compliance toward genuinely circular and socially responsible event practices.

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FOREIGN DIRECT INVESTMENT AND ECONOMIC GROWTH: EVIDENCE FROM OECD COUNTRIES (2010-2023)

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This study analyzes the impact of foreign direct investment (FDI) on economic growth in OECD countries, using secondary data from the World Bank, International Monetary Fund, and OECD for 2010–2023. For empirical analysis, fixed- and random-effects models, as well as multiple linear regression, were employed. The results show that FDI, trade openness, and inflation positively influence economic growth, whereas government expenditures negatively affect it, highlighting the need for improved public financial management. Consequently, the study recommends that policymakers shift public spending to productive investments and adopt strategies that promote long-term growth and sustainability. The originality of this study stems from the use of reliable data and empirical analysis focused on developed OECD countries.

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1 Introduction

Foreign Direct Investment (FDI) is recognized as a significant driver of economic growth in many countries, primarily through capital inflows, technology transfer, productivity gains, and employment generation. Economic growth theories suggest that FDI serves not only as a source of capital but also as a mechanism for accelerating development by expanding capital stock and enhancing technological capabilities in host countries (Solow, 1956; Romer, 1994).

Empirical literature substantiates that FDI positively and significantly drives economic growth, especially in developed economies where institutions and economic conditions support such investment. FDI boosts output by spreading knowledge, enhancing managerial skills, and connecting host economies to global markets. With sound macroeconomic policies and effective governance, foreign investment fosters sustainable economic growth (Ghosh, 2025).

However, FDI's impact on economic growth differs across countries and varies with structural and institutional factors. Empirical studies yield mixed results, indicating that FDI's ability to boost growth depends on human capital, financial market maturity, trade openness, and institutional quality. Without these conditions, FDI may not deliver significant growth benefits and can even crowd out domestic investment (Alfaro et al., 2004).

In this context, assessing how foreign direct investment shapes economic growth in developed countries remains a complex research task. A thorough approach is essential one that considers not only foreign capital inflows, but also domestic economic structures, institutional frameworks, and policy environments, all of which can intensify or reduce FDI's effects on economic performance.

2 Literature Review

The economic literature associates the impact of foreign direct investment (FDI) on economic growth with both classical and modern growth theories. Solow's (1956) neoclassical growth model highlights the significance of capital accumulation and technological progress in sustaining long-term growth, positioning FDI as an additional source of capital that can increase output levels. Nevertheless, within this

framework, the effect of FDI is primarily regarded as short-term, since marginal returns to capital diminish over time.

Endogenous growth theories contend that FDI exerts a long-term impact by facilitating the transfer of technology, managerial expertise, and innovation. According to Romer (1990, 1994) and Lucas (1988), the expansion of human capital and the diffusion of knowledge are central to sustaining economic growth. Through these mechanisms, FDI can enhance total factor productivity in host countries.

Early empirical studies report mixed findings regarding the impact of foreign direct investment (FDI) on economic growth. Borensztein (1998) presents a widely cited analysis, indicating that FDI positively influences economic growth only when the host country possesses a minimum threshold of human capital, clarifying that economic benefits are conditional on sufficient skills in the workforce. The study further asserts that FDI is more effective than domestic investment when the host country has the requisite skills to absorb foreign technology, again reinforcing this conditional relationship.

Balasubramanyam (1996) argues that FDI's long-term benefits for economic growth are greater in open economies with liberal trade policies, and that these effects rely on specific policy settings. Conversely, Carkovic and Levine (2005) question whether FDI directly and lastingly promotes long-term economic growth, arguing that its effect instead depends on institutional factors and the host country's policies, emphasizing its conditional nature.

A substantial body of literature supports the view that FDI's long-term effects on economic growth are conditional, depending on specific country characteristics. For example, Alfaro et al. (2004) show that FDI promotes long-term growth mainly in countries with developed financial markets, where robust systems enable efficient capital allocation and productive activities.

Hermes and Lensink (2003) reach similar conclusions, arguing that weak financial systems limit the benefits of FDI and, in some cases, may lead to negative outcomes. Similarly, Agosin and Machado (2005) identify cases where FDI may substitute domestic investment (“crowding out”), particularly in economies with limited absorptive capacity.

Recent empirical research shows that foreign direct investment (FDI) boosts economic growth. Country-specific conditions shape this effect. For example, Ghosh and Saha (2025) report that FDI increases GDP growth in developing countries, especially when institutional quality is high. Chizema (2025) finds that FDI inflows drive economic development in South and Southeast Asia by enabling technology transfer and integration into global value chains. Studies also indicate that FDI's impact on income inequality depends on human capital and governance (Li, 2025). Systematic reviews confirm that FDI can drive growth, but its success depends on internal capacities and policies. In developed countries, FDI tends to have more stable but sometimes smaller marginal effects on growth due to already advanced markets and technologies (Alfaro et al., 2004). Systematic reviews confirm that FDI can drive growth, but its success depends on internal capacities and policies.

The impact of FDI on sustainable growth is determined not only by capital inflows, technology transfer, and market access, but more importantly by complementary factors such as human capital, financial market development, and governance quality. For example, Azman-Saini et al. (2019) show that strong institutions significantly enhance the positive effects of FDI on growth implying that without such factors, the benefits of FDI may be limited.

Moreover, recent reports by UNCTAD (2023) emphasize that the quality of FDI, particularly investments in manufacturing and high-technology sectors, is more likely to generate sustainable growth than resource-driven FDI. Therefore, while FDI can be a catalyst for economic development, its positive impact is not automatic and varies significantly across countries depending on absorptive capacity and policy frameworks.

This section presents a comprehensive summary of the literature review that integrates findings from multiple studies through statistical synthesis guided by a systematic methodological approach. The central argument is that synthesizing these studies provides a clearer understanding of overarching trends, as detailed in the accompanying table summarizing the authors, publication years, variables, methods, and key findings.

Table 1: Summary of papers

Author	Year	Variables	Method	Findings
(Ikani, 2024)	(1991-2022)	FDI, inflation rate, trade openness, labor force, domestic credit to the private sector.	PMG Model	Foreign direct investment (FDI) plays a complex role in West Africa's economic development, showing a non-significant positive effect on long-term growth, a significant negative short-term impact, and an increase in unemployment rates over both periods. Thus, while FDI slightly benefits long-term growth, it worsens short-term growth and unemployment overall.
(Nuzhat, 2009)	(1980-2006)	FDI, labor force, real inflation rate.	GMM Model	The findings show that as Pakistan's GDP increases, FDI inflows tend to decrease. This suggests that to make FDI more beneficial for economic growth, Pakistan should focus on improving infrastructure, investing in human capital, fostering local entrepreneurship, and creating conditions that encourage productive investment.
(Ahmed. Khder, 2018)	(1980-2012)	FDI, domestic investment, export and import, and trade liberalization.	Vector Autoregression Model (VAR)	An empirical analysis using a vector autoregression model indicates that there is no long-term relationship between foreign direct investment and economic growth in Turkey.
(Hlaváček & Beata Bal, 2016)	(2000-2012)	Foreign direct investment, gross capital, inflation rate.	The Endogenous Growth Model.	Similarly, the findings indicate that foreign direct investment contributes to economic growth in Central and Eastern European countries. However, as production costs rise in specific locations within these countries, firms tend to shift their investments to other areas within Central and Eastern Europe that offer lower costs or higher value-added opportunities. This movement illustrates firms' efforts to maximize efficiency and returns by relocating within the region.
(Kyuntae & Hokyung, 2008)	(1975 - 2006)	Foreign direct investment, exports and imports, government spending.	Panel data model.	In addition, the results demonstrate that foreign direct investment and domestic capital are statistically significant in both the long and short run, exerting positive effects on economic growth in Ireland. The analysis also reveals a bidirectional Granger causality between GDP and foreign direct investment, supporting the validity of the FDI-led growth hypothesis for the Irish economy.

Source: Data processed by the authors

The summary of the literature review indicates that foreign direct investment (FDI) serves as a significant source of capital and contributes to infrastructure development, job creation, increased productivity, export growth, and the dissemination of technology and knowledge. Consequently, FDI influences economic development and sustainable growth however, these benefits depend on

careful management and the implementation of appropriate strategies by host countries to maximize advantages and mitigate potential risks.

3 Materials and Methods

The purpose of this scientific research is to analyze the impact of several macroeconomic factors on the economic growth of OECD countries. Specifically, the study focuses on the roles of foreign direct investment, trade openness, the inflation rate, and government expenditure in promoting economic growth, while also examining how these factors mitigate the risks of economic instability.

The research analyzes the period 2010–2023. The sample includes OECD members at varying levels of development, such as Poland, the Czech Republic, Turkey, Germany, France, Spain, Italy, the Netherlands, Sweden, and Greece. The study uses annual secondary data from official sources, including the OECD, IMF, and World Bank. This ensures comparability across countries and time.

To analyze the data and derive empirical results, econometric models and statistical tests will be employed using SPSS and Microsoft Excel. The main methods include linear regression, random-effects models, fixed-effects models, and linear trend analysis. These methods will help assess the relationship and impact of the independent variables on economic growth.

3.1 Research Questions

This section presents the main research questions examining the impact of foreign direct investment and key macroeconomic factors on economic growth, as well as differences in these effects across the studied countries.

- What is the impact of FDI and other macroeconomic factors on economic growth?
- How do FDI and government expenditure affect economic growth?
- Does the impact of FDI and macroeconomic factors differ among the studied countries?

3.2 Research Hypothesis

The following hypotheses are established to assess the impact of foreign direct investment on economic growth in OECD countries.

H0: Foreign Direct Investment has no statistically significant impact on economic growth in OECD countries.

H1: Foreign Direct Investment has a statistically significant impact on economic growth in OECD countries.

3.3 Specification of the econometric model

To evaluate the impact of foreign direct investment on economic growth in developed countries, the following multiple econometric model is proposed:

$$GDP = \beta_0 + \beta_1 FDI + \beta_2 TO + \beta_3 IR + \beta_4 GE + \varepsilon \quad (1)$$

3.4 Description of Variables

The table presents a detailed description of the variables included in the study, clarifying their roles and significance within the econometric analysis.

Table 2: Description of the variables included in the econometric model

Variable	Description	Data Source
Dependent variable (Y ₁)	Economic growth (GDP)	World Bank/OECD (2010-2023)
Independent variable (X ₁)	Foreign direct investment (FDI)	World Bank/OECD (2010-2023)
Independent variable (X ₂)	Trading opening (TO)	World Bank/OECD (2010-2023)
Independent variable (X ₃)	Inflation rate (IR)	World Bank/OECD (2010-2023)
Independent variable (X ₄)	Government Expenditure (GE)	World Bank/OECD (2010-2023)

Source: Data processed by the authors

Gross Domestic Product (GDP) – Refers to the increase in the total production of goods and services in an economy over a given period, measured by Gross Domestic Product.

Foreign Direct Investment (FDI) – Represents long-term investments made by foreign entities that provide significant control or influence over the economic activities of the host country.

Trade Openness (TO) – Indicates the degree of an economy's integration into international trade through imports and exports.

Inflation Rate (IR) – Represents the general and sustained increase in price levels, which reduces the purchasing power of money.

Government Expenditure (GE) – Refers to the funds spent by the government to finance public services and economic activities.

4 Results

This chapter presents the data analyses and study results, including descriptive statistics, histograms, probability plots, fixed- and random-effects models, and linear regression. All analyses were conducted in SPSS, enabling clear, detailed interpretation of the data and the identification of relationships and impacts among the variables under study.

Table 3: Descriptive statistics

	Mean	Std. Deviation	N
Gross Domestic Product.	1.62	4.096	140
Foreign Direct Investment	2.988	8.6293	140
Trade Openness	88.131	34.3242	140
Inflation Rate	4.00	10.323	140
Government expenditure	20.64	3.438	140

Source: Authors' calculations in SPSS program

The table of descriptive statistics presents the behavior of the main variables across 140 observations, where GDP and FDI exhibit relatively high standard deviations, indicating pronounced fluctuations over the analyzed period, while trade openness shows a high mean reflecting a considerable level of integration into international trade, albeit with noticeable variability. The inflation rate displays significant

instability, as evidenced by a high standard deviation relative to its mean, whereas government expenditure appears more stable, with lower variation compared to the other variables, suggesting a more consistent fiscal role in the economy.

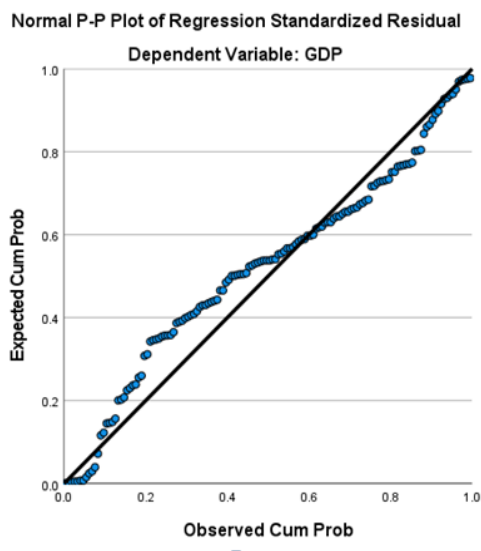


Figure 1: Macroeconomic indicators
Source:Authors' calculations in SPSS program

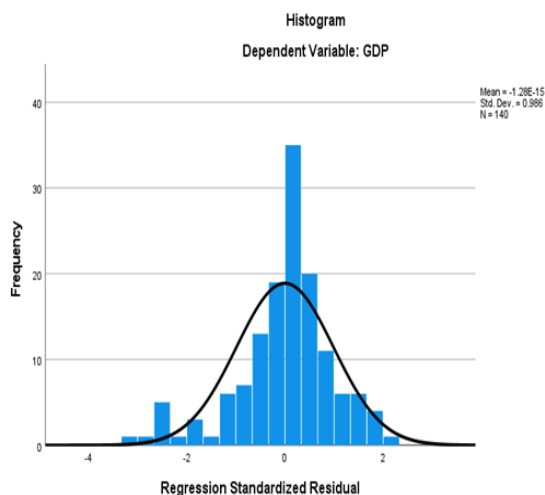


Figure2: Graphical representation of the histogram
Source:Authors' calculations in SPSS program

According to the probability plot, we can observe a very strong linear relationship between GDP and the independent variables (FDI, trade openness, inflation rate, and government expenditures), as the data points are positioned very close to the regression line. This indicates that the independent variables have a clear and consistent impact on GDP, suggesting that changes in each of these factors are closely associated with changes in the gross domestic product.

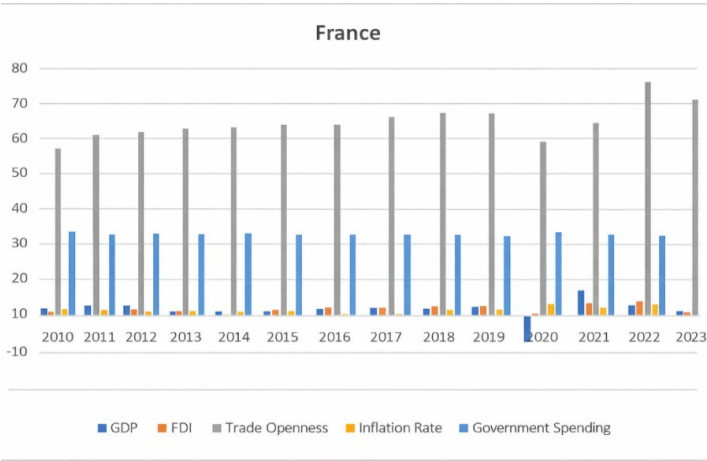


Figure 1:Macroeconomic Indicators in France (2010–2023)
Source: Authors’ calculations using Microsoft Excel

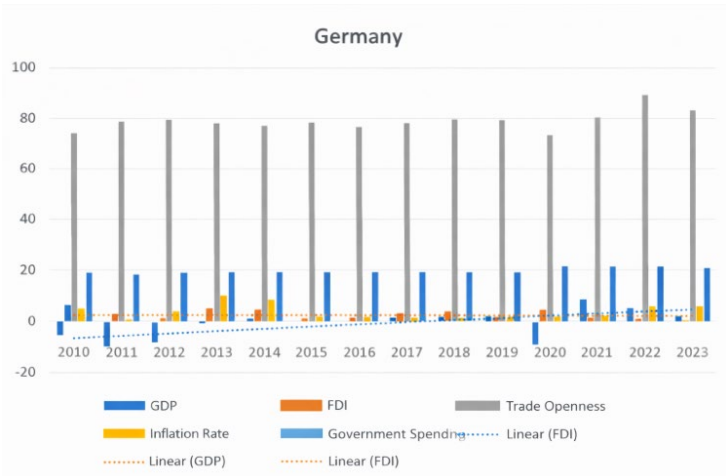


Figure 2:Macroeconomic Indicators in Germany (2010–2023)
Source: Authors’ calculations using Microsoft Excel

The chart shows that from 2010 to 2023, France's economy experienced steady GDP growth, except for a sharp decline in 2020 due to COVID-19, followed by a strong recovery. Foreign Direct Investment remained positive with minor fluctuations, reflecting a stable investment climate. Trade openness trended upward over the long term, indicating growing international integration, with only a temporary dip during the global crisis. Inflation stayed low until 2020, then rose significantly by 2023. Throughout, high government spending underscored the state's active economic support.

The chart illustrates Germany's economic performance from 2010 to 2023. Over most of the period, GDP growth remained relatively stable, though there were noticeable contractions in 2011 and a sharp decline in 2020 caused by the COVID-19 pandemic; subsequent years saw a strong recovery. Similarly, Foreign Direct Investment (FDI) exhibits moderate fluctuations, indicating varying investor confidence across the period but an overall stable trend. Trade openness also remains consistently high, highlighting Germany's strong integration into global trade, despite a temporary decline around 2020. Inflation stayed low and stable for most years, but rose significantly after 2021 due to global supply shocks and energy price pressures. Finally, government spending shows a steady, slightly increasing trend, reflecting the active role of fiscal policy in supporting economic stability and the post-crisis recovery.

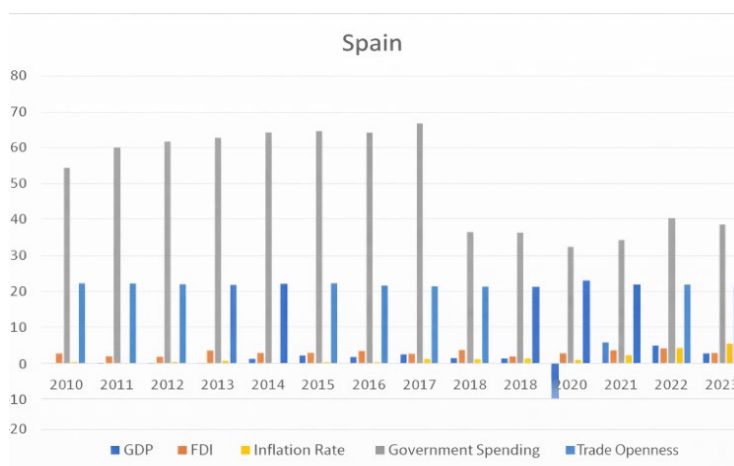


Figure 3: Macroeconomic Indicators in Spain (2010–2023)

Source: Authors' calculations using Microsoft Excel

The chart shows Spain's economic developments from 2010 to 2023, highlighting a generally stable GDP trend with moderate growth over most of the period. This is followed by a sharp contraction in 2020 due to the COVID-19 pandemic, followed by a gradual recovery thereafter. Meanwhile, Foreign Direct Investment (FDI) remains positive but relatively volatile, reflecting changes in investor confidence across different years. Government spending increases steadily until around 2017, then declines noticeably after 2018, indicating a shift toward fiscal consolidation, meaning efforts to reduce government deficits and debt levels with renewed support during the post-pandemic period. Similarly, trade openness remains relatively stable throughout the period, underlining Spain's continued integration into international markets. Inflation stays low for most of the years but rises significantly after 2021, reflecting broader global inflationary pressures linked to energy prices and supply chain disruptions.

Table 4: Fixed effect regression

GDP	Coef.	Robus Std.Err.	T	P> t	[95% Conf.	Interval
FDI	.0355384	.0100954	3.52	0.007	.0127011	.0583757
TO	.1414654	.0643034	2.20	0.055	-.0039989	.2869297
IR	-.0777734	.0206976	-3.76	0.005	-.1245947	-.0309521
GE	-1.073025	.9820935	-1.09	0.303	-.3.294675	1.148624
_cons	11.49681	24.67979	0.47	0.652	-.44.33275	67.32638

Source: Authors' calculations in SPSS program

The fixed-effect regression results show that increased FDI significantly raises GDP ($\beta = 0.0355$, $p = 0.007$), emphasizing FDI's positive contribution to economic growth. Trade openness has a positive, marginally significant effect ($p = 0.055$), suggesting a possible role in promoting GDP growth. The inflation rate exerts a negative, statistically significant effect ($\beta = -0.0778$, $p = 0.005$), which means higher inflation restricts economic growth. Government expenditure has a negative but statistically insignificant effect ($p = 0.303$), suggesting minimal impact on GDP. The constant term is also not statistically significant, confirming that GDP variations are mainly explained by the model's variables.

Table 5:Random effect regression

GDP	Coef.	Robus Std.Err.	Z	P> t	[95% Conf.	Interval]
FDI	.0217086	.0119805	1.81	0.070	-.0017727	.04519
TO	.038258	.0206323	1.85	0.064	-.0021807	.0786966
IR	.0003665	.0302886	0.01	0.990	-.0589979	.059731
GE	-.5222785	.2906768	-1.80	0.072	1.091994	.0474375
_cons	8.956337	5.360218	1.67	0.095	1.549497	19.46217

Source:Authors' calculations in SPSS program

The random effects model shows that FDI and trade openness positively affect GDP. These effects are marginally significant, with p-values of 0.070 and 0.064. This means the relationship is suggestive but not conventionally significant ($p < 0.05$). The inflation rate does not significantly affect economic growth ($p = 0.990$), whereas government spending has a negative, nearly significant effect ($p = 0.072$), which may restrain GDP growth. The constant term is not significant, so the variables only partially explain GDP variations.

Table 6:Multiple linear regression

GDP	Coef.	Robus Std.Err.	T	P > t	[95% Conf.	Interval]
FDI	.0233382	.0216257	1.08	0.282	-.0194307	.0661071
TO	.0226998	.0086927	2.61	0.010	.0055083	.0398914
IR	.0460701	.027695	1.66	0.099	-.0087021	.1008422
GE	-.3434809	.1049896	-3.27	0.001	-.5511181	-.1358437
_cons	6.450297	2.086496	3.09	0.002	2.323849	10.57674

Source:Authors' calculations in SPSS program

The results of the multiple linear regression indicate that trade openness has a positive and statistically significant effect on GDP ($\beta = 0.0227$, $p = 0.010$), meaning that, holding other variables constant, a one-unit increase in trade openness is associated with a 0.0227-unit increase in GDP. Government expenditure shows a negative, statistically significant effect ($\beta = -0.3435$, $p = 0.001$): a one-unit increase in government spending is associated with a 0.3435-unit reduction in GDP. The

inflation rate shows a positive effect (β = not reported) at the threshold of significance ($p = 0.099$), indicating that a one-unit increase in inflation is associated with a marginal rise in GDP. FDI does not have a significant impact on GDP ($p = 0.282$). The constant term is positive and statistically significant, representing the baseline GDP level when all other variables are zero.

5 Conclusions

This study analyzed the impact of foreign direct investment (FDI) on the economic growth of OECD developed countries over approximately 14 years. Based on the analyses, we found that most variables are clearly interrelated and statistically significant, except for government expenditures, which showed a negative association with economic growth.

According to the findings, three variables foreign direct investment, trade openness, and inflation rate are particularly significant for economic growth. These results highlight the importance of policies that strengthen these factors. Prioritizing such strategies will not only sustain economic growth but also enhance long-term resilience and competitiveness among OECD countries.

Regarding government expenditures, the analysis indicates the need for a more targeted and effective approach. It is recommended that governments focus on spending that supports long-term economic development, develop strategies for productive investments, and manage financial resources efficiently to enhance economic stability and sustainability.

This study analyzed the impact of foreign direct investment (FDI) on the economic growth of OECD developed countries over approximately 14 years. The results indicate that most variables are interrelated; however, their statistical significance and direction vary across different model specifications. Government expenditures generally show a negative association with economic growth.

The findings suggest that foreign direct investment, trade openness, and inflation may play an important role in economic growth. However, the impact of FDI is not consistently statistically significant across all models, and the effect of inflation appears sensitive to model specification, showing both positive and negative

relationships. These mixed results imply that the relationship between these variables and economic growth is complex and context-dependent.

Regarding government expenditures, the analysis indicates the need for a more targeted and efficient approach. It is recommended that governments prioritize spending that supports long-term economic development, promote productive investments, and manage financial resources effectively to enhance economic stability and sustainability.

Additional recommendations based on the study results:

- Encourage policies that attract and facilitate foreign direct investment through incentives and improved investment climate.
- Promote trade liberalization while ensuring a balanced approach to protect domestic industries.
- Maintain moderate and stable inflation through sound monetary policies to support economic growth.
- Optimize government spending by prioritizing infrastructure, education, and innovation, which have long-term economic benefits.
- Develop monitoring mechanisms to regularly evaluate the impact of fiscal policies and public investments on economic performance.

In summary, this study presents robust and persuasive findings that enhance understanding of the primary determinants of economic growth in OECD countries, including clear evidence of any negative effects, and offers actionable guidance to inform the development and implementation of more effective economic policies.

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ARTIFICIAL INTELLIGENCE TRANSFORMATION IN HIGHER EDUCATION: STUDENT LITERACY, ETHICAL PERCEPTIONS, AND INSTITUTIONAL GOVERNANCE

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The rapid integration of Artificial Intelligence (AI) into higher education poses significant challenges for institutional management and sustainable governance. This paper examines the ongoing AI transformation by exploring three primary dimensions: student AI literacy, ethical perceptions of academic integrity, and the psychological impacts of technology adoption. Employing a Systematic Literature Review (SLR) that strictly follows PRISMA guidelines, this study systematically reviews 42 recent peer-reviewed articles from the Scopus database, extracts 12 core studies, and maps the multifaceted effects of generative tools such as ChatGPT, Copilot, and Gemini. The findings reveal a critical “illusion of competence”, where students’ technical proficiency significantly outpaces their critical evaluation skills. The lack of clear institutional directives exacerbates unintentional academic over-reliance and blurs ethical boundaries. The review highlights a rising phenomenon of algorithmic anxiety, primarily driven by the deployment of unreliable AI content-detection systems that undermine the student-educator trust dynamic. This research also underscores the necessity for universities to transition from restrictive policies to comprehensive educational frameworks, ensuring the responsible use of generative technologies while safeguarding students’ cognitive development and mental well-being.

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1 Introduction

The rapid integration of Artificial Intelligence (AI) into the higher education sector has initiated a profound digital transformation, fundamentally altering traditional academic practices. Generative AI tools, such as ChatGPT, Copilot, and Gemini, are increasingly utilized by students and educators alike, presenting both unprecedented opportunities and significant challenges for institutional management. Recent studies emphasize that AI can customize learning experiences, streamline administrative processes, and improve student productivity (Mwakalinga & Mabilika, 2025; Vaněček et al., 2025). This shift toward highly interactive technological engagement mirrors the paradigm shifts observed in digital environments, such as the metaverse, where user perceptions and immersive participation have fundamentally redefined traditional boundaries (Szeberényi et al., 2025). Just as users navigate new forms of interaction in virtual spaces, students are adapting to an academic landscape heavily mediated by generative algorithms, requiring institutions to reassess their readiness and governance frameworks (Benayoune et al., 2026).

However, this rapid technological adoption simultaneously introduces complexities regarding student literacy, ethical perceptions, and academic integrity. Research indicates that while AI offers substantial benefits, excessive dependence on these systems can diminish essential cognitive skills, such as independent problem-solving and critical thinking (Abubakar et al., 2025). This over-reliance often leads to a superficial engagement with learning materials, raising significant ethical concerns about academic dishonesty and the blurring of authorship lines. As Maleki (2026) points out, the age of artificial intelligence requires a complete rethinking of ethical academic integrity ecosystems, moving beyond mere policy enforcement to cultivate genuine academic honesty.

A critical, often-overlooked dimension of this rapid digital shift is its psychological impact on the student body. The pressure to master emerging AI tools, coupled with uncertainties surrounding the ethical boundaries of their use, has led to rising levels of academic and technology-induced anxiety. The emotional dimension of technology adoption is complex; while some evidence suggests that moderate AI use can alleviate academic stress by providing immediate learning support (Ajlouni et al., 2025), the broader transition often triggers anxiety about performance expectations

and the fear of accidental plagiarism (Budhathoki et al., 2024). Furthermore, the implementation of unreliable AI content detectors has introduced new sources of stress, as students navigate the unpredictable nature of these evaluation tools (Hadra et al., 2026). Students frequently experience distress over maintaining a competitive edge in a rapidly shifting landscape, which complicates their relationships with these generative platforms.

The disparity between students' technical proficiency and ethical understanding remains a pressing issue. A lack of clear institutional policies exacerbates these ethical dilemmas, leaving students without proper guidance. Gonsalves (2026) notes that students often fall into a “transparency trap”, where the seamless output of generative AI increases their interpretive cognitive load, making it difficult to distinguish between authentic learning and automated assistance. It is essential to understand these varied attitudes and psychological responses to develop well-balanced regulations that encourage the advantageous use of AI while mitigating the risk of abuse.

This paper examines the AI transformation through the dual lens of usage patterns and ethical risk awareness, integrating the variables of academic stress and student literacy. By addressing the significant gap between technical capabilities and ethical understanding, this study aims to lay the foundation for developing sustainable management strategies. These strategies are crucial for aligning technological innovation with ethical standards and student well-being, ensuring long-term institutional adaptation in the digital era.

2 Literature Review

This section provides a comprehensive synthesis of the most recent academic discourse surrounding the integration of generative AI in higher education. To contextualize the multifaceted impact of these technologies on the student body, the review is structured around three primary dimensions: the evolution of AI literacy, ethical complexity, and psychological implications.

2.1 The concept of AI literacy and student adaptation

The introduction of generative algorithms has necessitated a fundamental reevaluation of digital literacy within academic settings. Chen et al. (2025) define AI literacy not merely as the technical capability to operate these platforms, but as a critical mindset essential for contextualizing and validating outputs. Although a significant majority of students actively use these systems for brainstorming and drafting, their critical approach to generated content remains highly inconsistent. Gonsalves (2026) describes this phenomenon as the „transparency trap”, noting that the fluency of technology-generated texts increases students' interpretive cognitive load. If students cannot adequately filter grammatically perfect but factually inaccurate outputs, the learning process is severely compromised.

Ngo (2023) emphasizes that AI literacy must be explicitly integrated into academic curricula to prevent the passive consumption of generated information. Aligning with this perspective, Perdana et al. (2026) argue that education must shift from a model of automation to one of augmentation, where artificial intelligence supplements rather than replaces cognitive effort. Similarly, immersive user interactions in the metaverse demand a higher, more complex level of cognitive engagement and adaptability from users (Szeberényi et al., 2025), and students in the educational space must develop an interactive, highly reflective relationship with AI tools. Stratton-Maher and Kelly (2026) support this stance, suggesting that future educational strategies should prioritize „learning with AI" rather than "learning from AI.”

2.2 Ethical perceptions and the risk of over-reliance

One of the most intensely debated topics in contemporary literature is the ethical ambiguity surrounding algorithmic assistance. Abubakar et al. (2025) examine in detail the phenomenon of over-reliance, in which students replace independent analytical thinking with automated responses. This practice not only reduces cognitive engagement but also normalizes academic shortcuts, frequently leading to unintentional plagiarism.

In a global context, Guadu et al. (2026) highlight that maintaining academic integrity faces particular obstacles in institutions where regulatory frameworks cannot keep pace with rapid technological advancements. When curricula lack specific guidelines for human-machine collaboration, ethical boundaries immediately blur. Uygun (2026) identifies the phenomenon of „clashing AIs”, where students use multiple different systems for writing, translating, and correcting, completely losing control over their own authorship. This fragmented tool usage reveals that subjective ethical norms often develop at the individual level due to significant institutional shortcomings.

2.3 The psychological dimension: Technostress and algorithmic anxiety

The psychological dimension of integrating artificial intelligence into education extends well beyond mere adaptation, emerging as a deep form of academic anxiety. This modern technostress is exacerbated by the extreme opacity of generative algorithms, which Bearman and Ajjawi (2023) describe as pedagogical black boxes. These systems provide immediate outputs without revealing the complex, multi-layered computational logic or the specific data sources behind their conclusions. This lack of epistemological transparency means students cannot evaluate how an AI arrived at a specific answer, forcing them to either blindly trust the machine or question every generated sentence.

When students do not understand the operational mechanics, hidden biases, or the exact limitations of the tools they use, their background anxiety rises significantly. This anxiety manifests as a continuous cognitive dissonance: the pressure to utilize AI for maximum efficiency clashes directly with the constant fear of algorithmic hallucinations and unverified information. Students exist in a persistent state of uncertainty, never fully confident that their AI-assisted work meets acceptable academic standards or that it is free of hidden errors that could negatively affect their academic performance later.

Recent research sheds light on a specific form of algorithmic anxiety generated directly by institutional controls. Numerous universities have introduced AI text-detection software; however, Hadra et al. (2026) and Perkins et al. (2024) demonstrate that these systems exhibit exceptionally high false-positive rates. The use of unreliable detectors instills constant fear, even among honest students who

submit entirely original work. Kirsanov et al. (2026) warn that excessive surveillance only prompts students to hide their use of the technology, leading them to adopt more advanced, deceptive methods rather than integrating the technology transparently. This atmosphere of distrust undermines the student-educator relationship, fostering a culture of monitoring rather than active mentoring and support.

3 Methodology

The research employed a Systematic Literature Review (SLR) to map the impact of generative AI integration in higher education. The methodology strictly followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a transparent and reproducible research process.

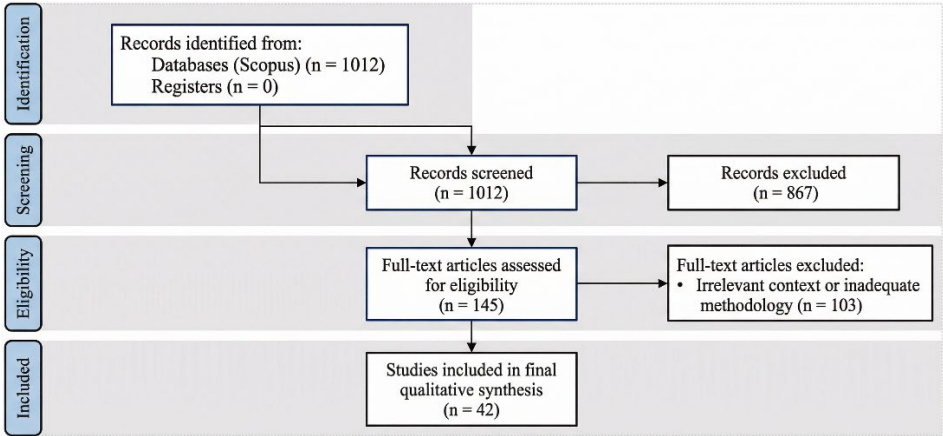


Figure 1: PRISMA Flow Diagram
Source: Own edited figure, 2026

3.1 Research design and search strategy

To construct a comprehensive dataset of high-impact academic literature, an extensive electronic search was conducted exclusively using the Scopus database. Scopus was selected as the primary data source due to its broad and rigorous indexing of highly ranked, peer-reviewed journals focusing on educational technology, institutional management, and psychology. The search strategy utilized a combination of Boolean operators applied to specific keywords within the titles,

abstracts, and keywords of the indexed documents. This approach aimed to capture the intersection of generative artificial intelligence adoption and its psychological or ethical impacts within the higher education sector. To ensure thematic precision and to directly apply the methodological inclusion criteria during the retrieval phase, the following exact Advanced Search query was executed in Scopus:

TITLE-ABS-KEY („Artificial Intelligence” OR „Generative AI” OR „ChatGPT” OR „Copilot” OR „Gemini”) AND TITLE-ABS-KEY („higher education” OR „university”) AND TITLE-ABS-KEY („student literacy” OR „academic integrity” OR „technostress” OR „algorithmic anxiety”) AND PUBYEAR > 2021

This specific search string was constructed to ensure both methodological breadth and thematic precision. The first set guarantees the inclusion of broad AI terminology alongside the specific generative models central to this study. The second set strictly isolates the higher education context, while the third set captures the exact psychological and ethical variables under investigation. Executing this broad query resulted in the initial identification of 1,012 records, which were subsequently subjected to the strict inclusion and exclusion criteria outlined in the screening phase.

3.2 Inclusion and exclusion criteria

To maintain the validity and relevance of the synthesized data, rigorous parameters were established for the selection of articles. The screening process evaluated studies based on publication date, document type, and thematic alignment. Table 1 outlines the strict parameters applied during the screening phase to ensure the literature synthesis remains highly focused and methodologically sound.

Table 1: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication Period	2022 - 2026	Pre-2022
Document Type	Peer-reviewed academic articles	Non-peer-reviewed sources, white papers
Language	English	Non-English publications
Thematic Focus	Generative AI use, academic anxiety, ethics	General AI architecture, machine learning code

Source: Own edited table, 2026

The temporal criterion (2022–2026) was specifically implemented to isolate the most recent advancements in generative AI, intentionally excluding older literature that predates the widespread availability of tools like ChatGPT, Copilot, and Gemini. Typologically, the selection was restricted exclusively to peer-reviewed academic articles to guarantee the highest level of scholarly rigor, thereby eliminating non-verified sources such as white papers or opinion pieces. The focus was deliberately narrowed to studies examining the exact intersection of generative AI adoption, ethical perceptions, and psychological dimensions within the higher education sector. Technical papers focusing purely on the backend programming or algorithmic architecture of machine learning models were excluded, ensuring the final dataset perfectly aligns with the educational and psychological objectives of this research.

3.3 Data extraction and quality appraisal

Following the initial retrieval, duplicate records were removed, and the remaining articles were screened by reviewing their titles and abstracts. Articles meeting the initial criteria were then subjected to a full-text review. To ensure objective quality appraisal and minimize selection bias, the inter-rater reliability of the included studies was calculated using Cohen's Kappa coefficient. The formula applied to determine the agreement level is:

$$\kappa = \frac{p_o - p_e}{1 - p_e} \quad (1)$$

Where p_o represents the relative observed agreement among reviewers, and p_e indicates the hypothetical probability of chance agreement. A calculated value of 0.85 was achieved, indicating strong agreement in the selection process. The extracted data from the final selection of articles was then categorized into thematic clusters corresponding to the research questions, forming the basis for the subsequent analytical sections.

4 Results

The systematic review of the 42 included articles revealed a complex, multidimensional reality regarding the integration of generative AI in higher education. It is important to note that the primary objective of this study is not to

provide an exhaustive, sequential analysis of every included article. Rather, the synthesis deliberately highlights the most essential and representative studies that offer novel insights, critical perspectives, or significant conceptual advancements. By extracting and synthesizing qualitative and quantitative data from this core literature, three primary thematic clusters were identified: deep disparities in student AI literacy, shifting paradigms and realities of academic integrity, and the measurable psychological burden on the student body.

To provide a structured overview of the synthesized literature, Table 2 categorizes the core studies extracted during the systematic review. The literature is grouped according to the three primary thematic clusters identified in the research: Student AI Literacy and Adoption, Academic Integrity and Institutional Governance, and Algorithmic Anxiety and Psychology. This matrix highlights the diverse methodological approaches and key findings that underpin the subsequent analysis.

Table 2: Synthesis of the included literature

Thematic Cluster	Author(s) & Year	Methodology / Context	Key Findings Synthesized
Student AI Literacy & Adoption	Chen et al. (2025)	Empirical survey	Identified the "illusion of competence" where operational fluency outpaces critical content evaluation.
	Ngo & Hastie (2025)	Pedagogical intervention	Highlighted that structured, guided AI use is required to transform passive consumption into independent problem-solving.
	Vaněček et al. (2025)	International comparison	Demonstrated varied international student attitudes towards AI integration and the need for holistic educational adaptation.
Academic Integrity & Institutional Governance	Abubakar et al. (2025)	Cross-sectional study	Documented the "over-reliance" phenomenon and how undefined institutional policies increase unintentional academic dishonesty.
	Benayoune et al. (2026)	Policy analysis (Oman)	Revealed that a lack of institutional readiness and restrictive policies actively hinder the ethical integration of AI tools.
	Guadu et al. (2026)	Conceptual framework	Emphasized the necessity of updating academic integrity guidelines to accommodate human-AI collaboration in diverse global contexts.
	Maleki (2026)	Ethical framework analysis	Proposed a complete rethinking of ethical academic ecosystems, moving away from simple disciplinary measures.

Thematic Cluster	Author(s) & Year	Methodology / Context	Key Findings Synthesized
	Eaton et al. (2025)	Qualitative narratives	Argued that generative AI disrupts traditional definitions of authorship, necessitating new evaluation metrics in a postplagiarism era.
Algorithmic Anxiety & Psychology	Perkins et al. (2024)	Empirical evaluation	Evaluated the efficacy of AI content detectors, demonstrating high false-positive rates that induce algorithmic anxiety and damage academic trust.
	Budhathoki et al. (2024)	Cross-country analysis	Linked the rapid adoption of ChatGPT directly to technology-induced anxiety, utilizing the UTAUT framework.
	Ajlouni et al. (2025)	Cross-sectional study	Measured the correlation between the high-intensity use of generative platforms and elevated levels of academic stress.
	Bearman & Ajjawi (2023)	Conceptual analysis	Described AI as pedagogical "black boxes" that increase cognitive friction and background anxiety among students.

Source: Own edited table, 2026

4.1 Illusion of competence and disparities in AI literacy

A recurring and significant finding across the synthesized literature is the sharp divergence between students’ mechanical proficiency with AI tools and their epistemological ability to validate the information generated. The data indicate an overarching „illusion of competence”. While over 80% of students in recent global surveys demonstrate high fluency in prompting platforms like ChatGPT, Copilot, or Gemini for initial drafting and ideation, fewer than 30% regularly cross-reference the algorithmic outputs with peer-reviewed, primary literature.

Chen et al. (2025) note that this operational reliance often circumvents essential cognitive processes. Students frequently conflate the linguistic fluency of generative models with factual accuracy, leading to a superficial engagement with the course material. The synthesis reveals that this lack of critical AI literacy disproportionately affects complex analytical tasks. For instance, while AI significantly accelerates data summarization, students who rely heavily on these tools without methodological understanding show a marked decline in their ability to synthesize opposing theoretical frameworks independently. Consequently, the literature emphasizes that mere access to generative AI does not equate to digital literacy; rather, without structured pedagogical intervention, it threatens to replace genuine cognitive skill acquisition with automated content curation.

4.2 The reality of academic integrity and the over-reliance phenomenon

The integration of generative technologies has fundamentally disrupted traditional frameworks of academic honesty, leading to what Abubakar et al. (2025) term the „over-reliance phenomenon”. The extracted data reveals that academic violations in the AI era are rarely malicious; rather, they are largely driven by institutional ambiguity and a systemic outsourcing of cognitive load.

When syllabi lack clear, concrete directives regarding acceptable human-AI collaboration, the incidence of unintentional plagiarism increases dramatically. Benayoune et al. (2026) report that students frequently cross ethical boundaries simply because those boundaries remain undefined. They found that in institutions lacking comprehensive AI guidelines, up to 65% of students admitted to using generative tools in ways they suspected might be penalizing, yet they continued to do so due to intense academic pressure and a lack of clear alternatives.

Furthermore, the review highlights that maintaining academic integrity is a highly contextual and global challenge. Guadu et al. (2026) demonstrate that universities operating with outdated integrity policies struggle to differentiate between legitimate technological assistance and unethical academic shortcuts. The findings consistently suggest that disciplinary measures alone are entirely insufficient. To protect the intrinsic value of academic degrees, institutions must redefine original authorship, acknowledging that modern academic work is increasingly a co-creative process between human intellect and algorithmic assistance.

4.3 Algorithmic anxiety and the psychological burden of detection systems

Perhaps the most concerning finding from the systematic review is the measurable, severe increase in psychological distress directly linked to the AI transition. The literature confirms that the persistent pressure to master emerging technologies to remain competitive introduces a modern, acute layer of technostress. However, the qualitative data reveal a more specific and damaging phenomenon: algorithmic anxiety, driven primarily by institutional responses.

Following the initial surge of generative AI, numerous educational institutions adopted AI text-detection software to enforce academic integrity. The synthesized studies, including the comprehensive analysis by Perkins et al. (2024), document that these commercial detection platforms exhibit notoriously high false-positive rates. The data shows that non-native English speakers and neurodivergent students are disproportionately flagged by these systems as utilizing AI, even when their work is entirely original.

This surveillance ecosystem has created a profound psychological burden. Students operating with complete integrity report a significant, ongoing fear of wrongful accusation, which actively diminishes their intrinsic academic motivation. The literature indicates that an over-reliance on unreliable detection mechanisms fundamentally damages the student-educator trust dynamic, shifting the academic relationship from mentorship to suspicion. The resulting algorithmic anxiety not only impacts mental health but also creates a chilling effect on academic expression, as students actively alter their natural writing styles to avoid triggering automated suspicion.

5 Discussion

The findings of this systematic review necessitate a comprehensive reassessment of how higher educational institutions manage the digital transition. The data reveals that simply providing access to generative AI without structured pedagogical support leads to an illusion of competence and heightened algorithmic anxiety. Therefore, university management must prioritize sustainable governance frameworks that promote critical digital literacy and protect student well-being.

5.1 Redefining management strategies and ethical frameworks

The significant divergence between technical fluency and ethical awareness requires immediate administrative intervention. The current reliance on restrictive policies and unreliable detection software is counterproductive. As Maleki (2026) suggests, institutions must cultivate transparent ethical ecosystems. To achieve sustainable governance, universities need to develop clear guidelines that explicitly define the boundaries of human-AI collaboration. This involves shifting the institutional focus from policing academic output to integrating critical AI literacy directly into the

curriculum. By transparently defining acceptable use cases, university management can significantly reduce the ambiguity that drives academic distress.

5.2 Transitioning to sustainable assessment paradigms

The data strongly support the need to adapt assessment methodologies. Traditional testing and essay-writing assignments are increasingly vulnerable to the over-reliance phenomenon. Educational managers and curriculum designers must implement alternative evaluation methods that measure critical thinking and the process of learning, rather than just the final written product. Table 3 outlines the strategic shifts required for sustainable institutional adaptation.

Table 3: Strategic shifts in institutional AI management

Dimension	Traditional Paradigm	AI-Integrated Paradigm
Policy Approach	Restrictive and disciplinary	Comprehensive and educational
Academic Integrity	Focus on plagiarism detection	Focus on ethical collaboration guidelines
Student Assessment	Evaluating the final written output	Evaluating critical thinking and process
Institutional Focus	Mitigating technological risks	Cultivating critical AI literacy

Source: Own edited table, 2026

Implementing these strategies is essential to developing long-term resilience in the higher education sector. By aligning technological innovation with updated ethical standards, institutions can effectively manage the digital transformation while safeguarding the cognitive development and mental health of their students.

6 Conclusion

This study synthesized current literature to examine the multi-dimensional impact of generative AI on higher education, focusing on student literacy, academic integrity, and algorithmic anxiety. The analysis confirms that while AI tools offer significant opportunities for efficiency, their unguided integration creates substantial challenges for institutional management.

The results indicate that high operational proficiency in generative models frequently masks a severe lack of critical evaluation skills, leading to an illusion of competence. Ambiguous institutional policies exacerbate the risk of academic over-reliance, as

students struggle to navigate undefined ethical boundaries. Most critically, the transition has introduced a new psychological burden. The deployment of flawed AI detection tools has disproportionately harmed the student-educator trust dynamic, causing significant distress and anxiety among the student body.

While this systematic review provides a thorough overview, it is limited by the rapidly evolving nature of generative technologies. The primary focus on English-language publications may also restrict the global applicability of the findings. Future research should prioritize empirical studies that measure the long-term cognitive effects of AI integration across different scientific disciplines. Additionally, investigating the specific socio-technical realities of developing regions will be crucial for establishing truly global, equitable frameworks for AI governance. Sustainable institutional management requires continuous adaptation, ensuring that the digital transformation serves to enhance, rather than replace, genuine academic inquiry.

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GREENWASHING AND GREENHUSHING IN THE HUNGARIAN CONSUMER MARKET

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This study investigates the impact of greenwashing and greenhushing on consumer trust in the Hungarian market. Based on an online survey of 410 respondents conducted between November 1, 2024, and March 10, 2025, the results are presented through three research questions focusing on conceptual awareness, recall of international scandals, and purchasing decision factors. Data analysis utilized descriptive statistics and two-sample Z-tests at a 5% significance level. Findings reveal that while the Volkswagen “Dieselgate” scandal is widely recognized, other major cases – such as Chevron or BP – show a rapid decay in public memory. Furthermore, 74% of participants were completely unfamiliar with greenhushing. Statistical tests confirm that the inability to identify the „Seven Sins of Greenwashing” is a systemic issue, with over 34% of respondents unable to name a single deceptive practice. Due to “label fatigue”, consumers bypass official certifications, prioritizing social media and brand reputation.

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1 Introduction

Sustainability has become a fundamental aspect of corporate operations, driven by escalating societal expectations regarding environmental responsibility. Consequently, corporate communication frequently emphasizes green commitments; however, these claims do not always reflect actual operational changes. This duality in domestic corporate practice was also identified by Kozma and Bosnyák-Simon (2022), pointing out that the appearance of sustainability elements in corporate communication often precedes actual operational-level shifts. Furthermore, understanding the various levels of corporate environmental strategies in Hungary is crucial for evaluating how organizations employ environmental management control tools to justify their market positions (Malovics et al., 2007; Fekete-Berzsenyi et al., 2025).

This deceptive communication practice, known as greenwashing, has emerged as a prominent subject in international research. Greenwashing occurs when organizations portray their environmental performance more favorably than their actual operations warrant, primarily to influence consumer decision-making (Agarwal et al., 2025). The strategic impact of integrated sustainability reporting on financial performance and credibility is highly relevant, especially as corporate claims are increasingly scrutinized in developing and emerging markets (Katherine et al., 2025; Pap et al., 2024). The proliferation of greenwashing poses a severe risk to consumer trust (Fűrész et al., 2026). When consumers perceive a discrepancy between corporate claims and actual environmental performance, it fosters long-term skepticism and diminishes interest in sustainable products. Therefore, the primary aim of this research is to explore the impacts of greenwashing on the evolution of consumer trust and to identify the critical factors that determine the perceived credibility of corporate environmental claims.

2 Literature Review

The examination of greenwashing has expanded significantly, with contemporary studies emphasizing that consumer trust is simultaneously shaped by the credibility of corporate communication, the interpretability of environmental claims, and market expectations regarding sustainability. Consumers are increasingly sensitive to messages that suggest overgeneralized or inadequately substantiated environmental performance (Zhang et al., 2025). Moreover, consumer engagement in online brand

communities significantly influences how the public interprets and validates sustainability messages (Venkateswaran et al., 2024). As the digital transition accelerates, interactive and immersive advertising in modern online environments reshapes user perceptions, demanding greater transparency from corporations to avoid accusations of greenwashing (Szeberényi et al., 2025).

2.1 Mechanisms and Typology of Greenwashing

The methodology of corporate deception operates fundamentally along two dimensions: textual claims and execution elements. The most prevalent framework for analyzing product-level deception is the “Seven Sins of Greenwashing,” originally developed by TerraChoice (now integrated into the UL network), which capitalizes on consumer information asymmetry (Delmas & Burbano, 2011; UL, 2025). This framework categorizes misleading practices into seven distinct „sins”: the hidden trade-off, no proof, vagueness, irrelevance, lesser of two evils, fibbing, and worshipping false labels. The most frequent manifestation is the sin of the hidden trade-off, in which a single eco-friendly attribute is highlighted while obscuring the severely polluting phases of the product's entire life cycle. Furthermore, a critical distinction must be made regarding corporate-level greenwashing, which occurs when heavily polluting “brown” entities heavily promote secondary CSR sustainability initiatives to deflect public attention from their core, harmful environmental footprint (Yang et al., 2020; Szép et al., 2025).

2.2 The Emergence of Greenhushing

In contrast to the overstatements characteristic of greenwashing, academic discourse has increasingly focused on its antithesis: greenhushing (or „green silence”). This phenomenon describes a deliberate corporate strategy wherein organizations under-communicate or conceal their actual sustainability achievements and targets, primarily driven by a fear of consumer skepticism and accusations of greenwashing (Font et al., 2017). Motivated by risk aversion and heightened regulatory pressures (such as the EU Green Claims Directive), companies often opt for „strategic silence” over transparency, even when possessing tangible, verifiable environmental results (Carlos & Lewis, 2018). Recent studies describe this as a market paradox: while consumers demand greater transparency to combat their growing distrust, credible actors withdraw from public discourse, inadvertently yielding space to less ethical, louder marketing campaigns.

Despite the extensive theoretical background on these phenomena, there remains a critical gap in empirical data on the specific defensive mechanisms of consumers and the reputational impact of corporate scandals in the domestic Hungarian market. Consequently, this study aims to address these deficiencies by systematically investigating the interplay between conceptual awareness (greenwashing, greenhushing), the perceived credibility of various information sources, and demographic variables.

3 Methodology

The primary research employed a quantitative methodology, using an online questionnaire comprising 28 items to address the research problem outlined in the literature review. Data collection occurred between November 1, 2024, and March 10, 2025. A convenience sampling method was used, primarily distributing the survey via online platforms such as social media and professional networks. After data cleaning, 410 valid responses were obtained. While this sample size is not strictly representative, it provides a sufficient empirical foundation for drawing relevant conclusions regarding consumer behavior. While the sample size allows an exploratory assessment of consumer perceptions, it should not be treated as representative of the broader Hungarian consumer market.

Regarding the sample's demographic composition, 54% of respondents were male, and 46% were female. The age distribution shows a dominance of young adults, with 56% of participants in the 18–34 age cohort, while the over-35 cohort accounted for 44%. In terms of educational attainment, the sample is highly qualified; the majority of respondents either possess or are currently pursuing a higher education degree. The use of convenience sampling, together with the concentration of respondents in the 18–34 age group and the predominance of participants with current or completed higher education, narrows the demographic coverage of the dataset. The findings, therefore, reflect the views of a digitally reachable and relatively highly educated segment more strongly than those of the Hungarian consumer population as a whole, so their generalizability is limited. Future research should apply quota-based or probability-oriented sampling to achieve a more balanced demographic structure.

The questionnaire incorporated open-ended, Likert-scale, and multiple-choice questions to capture a comprehensive view of consumer perceptions. The data analysis primarily utilized descriptive statistical methods, focusing on frequencies and distributions. Additionally, to examine differences between demographic groups, statistical tests – specifically two-sample Z-tests – were conducted at a 5% significance level where the sample size permitted. For each gender-based comparison, the null hypothesis (H0) stated that the proportion of male and female respondents in the examined response category was equal, while the alternative hypothesis (H1) stated that these proportions differed.

The research is fundamentally exploratory, aiming to identify contemporary patterns in consumer attitudes and knowledge. Consequently, the study formulated the following three research questions:

- RQ1: To what extent are Hungarian consumers aware of the concepts of greenwashing and greenhushing?
- RQ2: To what extent are corporate greenwashing scandals that generated significant international resonance known among domestic consumers?
- RQ3: Which factors are most decisive during sustainable purchasing decisions, and how does the perception of deception impact consumer trust?

4 Results

This section presents the empirical findings derived from the online survey. The analysis is structured to systematically address the three primary research questions, beginning with an assessment of conceptual awareness regarding deceptive corporate communication. It also evaluates the domestic consumer knowledge of major international corporate scandals and concludes by examining the primary information sources and cognitive heuristics that drive sustainable purchasing decisions.

4.1 Conceptual Awareness of Greenwashing and Greenhushing

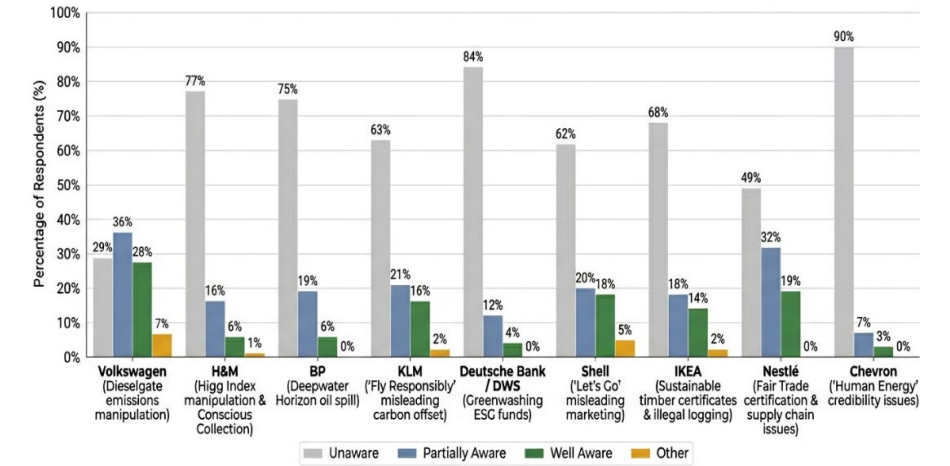
To address the first research question (RQ1), the survey initially assessed the general awareness of the term „greenwashing”. The results indicate a critical deficiency in consumer education: a significant segment of respondents (28%) could not define

the term at all, and an additional 13% had heard of it but lacked a precise understanding. Conversely, a positive indicator is that 38% had a general understanding, and 21% could define the concept accurately. This distribution validates the information asymmetry discussed in the literature; while consumers frequently encounter greenwashing, many lack the cognitive tools to identify it precisely.

A deeper discrepancy emerges regarding the phenomenon of „greenhushing”. The data reveal a contrast in awareness: 74% of respondents were completely unfamiliar with the term. Only 5% could define it accurately, while 9% possessed a marginal understanding. This indicates that greenhushing remains confined to professional discourse. Consequently, consumers are currently unequipped to respond when companies adopt a „strategic silence” strategy.

4.2 Consumer Knowledge of Corporate Scandals

The second research question (RQ2) investigated the awareness of major international corporate greenwashing scandals. Respondents were presented with nine highly publicized cases spanning various sectors (fossil fuels, technology, aviation, fast fashion, and finance).



Note: Data indicates varying degrees of public awareness of public-facing greenwashing accusations across different industries and company profiles. n = 410

Figure 1: Public Awareness of Major Corporate Greenwashing Scandals
Source: Own edited figure based on primary research, 2026

The analysis of Figure 1 highlights a profound lack of awareness regarding the majority of these events. The Volkswagen „Dieselgate” scandal stands out as an anomaly, with 36% partial and 28% comprehensive awareness, largely due to its direct impact on everyday consumers and extensive global media coverage. On the other hand, 90% were unaware of Chevron's controversies, 84% were ignorant of Deutsche Bank's ESG manipulation, and 75% had no recollection of the BP oil spill, indicating a significant decay in reputational damage over time. Complex, data-driven deceptions (such as those by H&M or KLM) struggle to reach the consumer threshold compared to clear-cut environmental disasters. This pervasive unawareness effectively shields corporations; consumers cannot exercise disciplinary market behaviors (e.g., brand avoidance) for corporate misconduct they do not remember.

4.3 Information Sources and Decision-Making Factors

Given the low retention of corporate scandals, the third research question (RQ3) explored the heuristics consumers rely on in an uncertain information environment. The findings identify a highly relevant and somewhat concerning trend: social media and news portals have become the primary sources of sustainability information. For evaluating product sustainability, 62% of respondents rely on these platforms, far outweighing official reports. This reliance on the least regulated platforms exposes consumers to a high risk of manipulation, particularly with the proliferation of unverified claims and AI-generated content. Scientific research and official environmental assessments were prioritized only when evaluating corporate-level sustainability (56%).

When analyzing the key factors influencing sustainable purchasing decisions using Likert-scale evaluations, a significant level of cognitive dissonance emerged. Respondents treat sustainability primarily as a matter of trust and reputation rather than technical verification. „Brand reputation” received the highest „very important” rating (28%). Surprisingly, a striking 40% of respondents rated official, third-party certificates (e.g., EU Ecolabel) as „not important at all,” and 31% expressed the same disregard for sustainable packaging. This data signals severe „label fatigue”. The prevalence of greenwashing has likely degraded trust in certification systems, prompting consumers to rely on subjective, emotional heuristics, such as brand image, rather than objective metrics. Furthermore, the willingness to pay a premium for verified green products is constrained, particularly

among the 18–34 demographic, which aligns with Csiszárík-Kocsir's (2023) findings on the financial uncertainties that limit conscious consumption among younger generations.

4.4 Knowledge of the „Seven Sins” Framework

To further evaluate consumer vulnerability, the study tested respondents' ability to name the „Seven Sins of Greenwashing” established by TerraChoice. The results confirm that consumer knowledge of deceptive practices is intuitive rather than systematic.

In line with the methodological specification, the category-level tests presented in Table 1 were based on the following hypotheses: H0: the proportion of male respondents in a given category equals the proportion of female respondents in the same category. H1: The two proportions differ.

Table 1: Two-sample Z-test analyzing the gender differences in identifying the „Seven Sins” of Greenwashing

Category (Number of “Sins” named)	Group	N	Proportion (%)	Std. Error	Z-value	p-value (2-tailed)
Could not name any	Male	76	34.4%	0.032	-0.337	0.736
	Female	68	36.0%	0.035		
Named one	Male	48	21.7%	0.028	-1.118	0.263
	Female	50	26.5%	0.032		
Named two	Male	41	18.6%	0.026	0.146	0.884
	Female	34	18.0%	0.028		
Named three	Male	25	11.3%	0.021	-0.433	0.665
	Female	24	12.7%	0.024		
Named four	Male	10	4.5%	0.014	1.010	0.312
	Female	5	2.6%	0.012		
Named five	Male	9	4.1%	0.013	1.127	0.259
	Female	4	2.1%	0.010		
Named six	Male	7	3.2%	0.012	1.039	0.298
	Female	3	1.6%	0.009		
Named seven	Male	5	2.3%	0.010	1.450	0.147
	Female	1	0.5%	0.005		

Note: Independent samples Z-test. Male n = 221, Female n = 189. Significance level: $p < 0.05$.

Source: Own edited table based on primary research, 2026

As demonstrated in Table 1, the largest group consisted of uninformed respondents: 34.4% of males and 36.0% of females could not identify a single „sin”. The independent-samples Z-test confirms that, at the 5% significance level, there is no

statistically significant difference between the genders in this critical category ($Z = -0.337$; $p = 0.736$). Even among those who could name exactly one category, the apparent difference (26.5% for women vs. 21.7% for men) proved to be statistically non-significant ($p = 0.263$). Similarly, the slight numerical advantage observed among men at higher knowledge levels (naming 4–7 sins) cannot be considered statistically significant due to the small sample sizes in these subgroups. The inability to systematically categorize and recognize greenwashing is not a demographic anomaly but a systemic vulnerability across the entire domestic consumer base. The inability to systematically categorize and recognize greenwashing appears in both gender groups within the surveyed sample, suggesting a broad vulnerability that should be interpreted cautiously in light of the study's sampling limitations.

5 Discussion

The results of this exploratory research highlight a significant vulnerability within the surveyed Hungarian sample regarding corporate environmental claims. The results of this exploratory research highlight a significant vulnerability within the Hungarian consumer market regarding corporate environmental claims. The data reveals a clear divide: while greenwashing is generally recognized as a concept, the actual mechanisms of deception remain poorly understood, and the emerging trend of greenhushing is almost entirely unknown. This aligns with the theoretical frameworks proposed by Font and his colleagues (2017) and Carlos and Lewis (2018), confirming that corporate strategies of „strategic silence” currently bypass consumer scrutiny, as buyers lack the conceptual foundation to identify or challenge them. This difficulty in distinguishing between genuine sustainability and mere appearances is further explained by signaling theory; misleading communications aim to foster overly positive beliefs among stakeholders, even when actual environmental practices remain deficient. Recent empirical studies, such as Margariti and her colleagues' (2024) analysis of consumer attitudes, demonstrate that positive psychological predispositions toward green purchases do not necessarily translate into actual buying behavior, especially when market trust is compromised by concerns about greenwashing.

The surprisingly low recall of major international greenwashing scandals indicates a rapid decay in reputational damage. Corporate misconduct, unless directly affecting the consumer's daily life or physical safety, fades quickly from public memory. This collective amnesia effectively shields companies from long-term market discipline.

Consumers fail to execute disciplinary purchasing decisions, which explains why heavily polluting entities can maintain market share despite documented environmental violations (Persakis et al., 2025; Yang et al., 2020). As noted by Torelli and his colleagues (2020), the level of greenwashing significantly shapes how stakeholders perceive corporate responsibility and how they respond to such scandals, yet the lack of awareness in the domestic market prevents these reactions from serving as a deterrent.

A critical shift identified in this study is the displacement of traditional, objective certifications by social media heuristics. As Fűrész and her colleagues (2025) note, the quality of information transfer in digital spaces fundamentally shapes energy awareness and sustainability attitudes. The reliance on digital platforms, compounded by the growing influence of interactive online communities (Venkateswaran et al., 2024), exposes buyers to unverified or artificially generated narratives. In this context, the role of social media influencers (SMIs) becomes paramount, particularly for Generation Z consumers who comprise a large portion of the active digital audience. Research by Faisal and his colleagues (2026) indicates that while influencers might not always directly drive purchase intentions, they exert a positive influence on both green trust and green attitudes, which are essential mediators in the sustainable decision-making process. The pronounced „label fatigue” observed in the sample supports recent empirical findings suggesting that an overabundance of green signals leads to systemic consumer skepticism. When buyers reject official certifications as „unimportant,” they default to evaluating brand reputation through subjective, often manipulated, digital media lenses.

Ultimately, respondents across all demographics' inability to identify the TerraChoice „Seven Sins” demonstrates that current consumer education is inadequate. Achieving genuine market transformation requires comprehensive initiatives that provide concrete evaluative tools, empowering consumers to navigate complex corporate communications effectively. Supporting this necessity, Volschenk and his colleagues (2022) found that general environmental education is often insufficient for developing the ability to detect deceptive claims. Instead, specific literacy regarding greenwashing itself is required to enable consumers to identify false claims and impose a „greenwash penalty” – a significant shift in willingness to pay and purchase intent once deception is recognized. A critical approach to green marketing will allow stakeholders to more easily distinguish

between legitimate companies that are responsible and those companies that simply appear to be responsible.

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ARTIFICIAL AUTHENTICITY: THE TRANSPARENCY PARADOX IN SME MARKETING

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This study examines how disclosure of Generative AI usage in SME marketing creates a "Transparency Paradox" that simultaneously demands and undermines consumer trust. An integrative literature review synthesizes empirical studies on AI disclosure effects with Signaling Theory and the Integrative Model of Organizational Trust, focusing on customer-facing communications where source authenticity underpins SMEs' competitive advantage. The analysis identifies a core tension: while customers demand transparency, explicit AI labeling triggers a "Word-of-Machine" effect and a Personalization Paradox, reducing perceived value and emotional connection in hedonic contexts; conversely, concealing AI usage constitutes "AI-washing," risking reputational damage upon exposure. For SMEs relying on relational proximity as a core asset, this paradox is damaging. Given limited longitudinal evidence, findings draw on case studies and cross-contextual inference. The research demonstrates that technical transparency is insufficient; SMEs require 'Artificial Authenticity' strategies emphasizing human-in-the-loop oversight, linking ethics washing to psychological rejection of automated agency in SME marketing.

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1 Introduction

Generative AI is rapidly reshaping how firms create and personalize marketing content, promising efficiency gains and new forms of value creation across industries (Davenport et al., 2020). For small and medium-sized enterprises (SMEs) - which account for a substantial share of global employment - these models significantly enhance productivity and customer engagement (Rajaram & Tinguely, 2024). This shift extends beyond marketing outputs, as the integration of artificial intelligence directly influences overall management productivity and operational efficiency (Garg et al., 2024). However, as Sarker et al. (2025) emphasize, this technological shift also amplifies critical concerns regarding algorithmic opacity and the erosion of stakeholder trust (Dwivedi et al., 2023).

In parallel, regulators and platforms increasingly frame transparency as the primary remedy. The EU AI Act and major platforms such as Meta and TikTok are moving toward mandatory labeling, making the disclosure of AI use a legal and infrastructural constraint rather than a voluntary ethical choice (Koning & Voorveld, 2025). Under the EU AI Act, which entered into force in August 2024 with transparency obligations applying from August 2026, AI systems that interact directly with consumers - including customer-facing chatbots and AI-generated marketing content - are subject to mandatory disclosure requirements (European Parliament and Council of the European Union, 2024, Art. 50). Providers must inform users that they are interacting with an AI system, and synthetic or AI-manipulated content must be labeled as such. While the Act includes proportionality provisions that acknowledge SMEs' more limited resources (European Parliament and Council of the European Union, 2024, Art. 55; Recital 91), smaller firms must nonetheless implement disclosure mechanisms and document their AI use without the dedicated compliance infrastructure typically available to larger organizations (Rajaram & Tinguely, 2024). Consequently, resource-constrained SMEs are forced to decide not whether, but how to integrate generative AI and signal its use to their audiences.

Recent empirical evidence, however, indicates that transparency itself is double-edged. Experimental work shows that AI disclosures in generative AI-created advertisements increase consumers' conceptual AI knowledge and activate persuasion knowledge, which in turn reduce trust in both the ad and the organization, even as perceived appropriateness can modestly increase trust (Koning

& Voorveld, 2025). Similarly, studies on social media content find that brands' adoption of generative AI - especially for full automation of content creation - undermines perceived brand authenticity and deteriorates attitudes, electronic word-of-mouth intentions, and loyalty, despite the fact that users often cannot perceptually distinguish AI- from human-generated content; the negative shift is triggered by disclosure (Brüns & Meißner, 2024). These findings point to a transparency paradox, in which making AI use visible can simultaneously uphold ethical ideals and erode consumer trust (Koning & Voorveld, 2025; Brüns & Meißner, 2024).

This paradox is particularly acute for SMEs, whose competitive advantage often rests on relational closeness, perceived genuineness, and locally grounded authenticity in their marketing interactions (Sarker et al., 2025). Yet previous research on AI disclosures and generative AI in marketing has largely focused on large brands, generic consumer contexts, or platform-level policy, paying limited attention to the specific vulnerabilities and trust dynamics of SME marketing.

To address this gap, the present paper introduces the notion of “artificial authenticity” and investigates the transparency paradox in SME marketing. Artificial Authenticity is a strategic communication framework in which an organization openly acknowledges its use of generative AI while simultaneously foregrounding the human expertise, curation, and oversight that guided the process, thereby maintaining perceived source authenticity, relational trust, and brand integrity without resorting to either concealment (AI-washing) or reductionist binary labeling ('AI-generated').

Specifically, this review addresses the following research questions:

- RQ1: How can "AI-Washing" be defined from the perspective of consumer trust, specifically regarding organizational integrity and benevolence?
- RQ2: How do the "Transparency Paradox" and the "Word-of-Machine" effect manifest in the context of SME marketing?
- RQ3: What strategic communication practices can SMEs employ to restore and maintain brand authenticity?

2 Theoretical Background

2.1 Defining AI-Washing in the SME Context (RQ1)

AI-washing represents the latest iteration in a documented family of corporate "washing" phenomena. The foundational analogy lies in greenwashing, defined by Delmas and Burbano (2011) as misleading consumers about a firm's environmental practices. De Jong, Huluba, and Beldad (2020) advance this framework by demonstrating that greenwashing operates along a spectrum: their experimental study distinguishes between outright lies, half-lies, and taking credit for legal obligations. Half-lies produce the same reputational damage as complete lies - consumers judge deception normatively, not proportionally (De Jong et al., 2020). According to cognitive dissonance theory (Festinger, 1957), this finding illustrates how consumers react to deceptive signaling: they resolve the tension between corporate claims and reality by questioning the organization's integrity, regardless of the severity of the discrepancy.

The transition from environmental to technological deception is mediated by the concept of "ethics washing." Bietti (2020) argues that technology companies instrumentalize ethics as a self-legitimizing strategy to deflect regulation, while Wagner (2019) positions ethical frameworks as deliberate substitutes for binding legal obligations - reducing AI governance to voluntary, unenforceable commitments. Seele and Schultz (2022) formalize this bridge by introducing the term "machinewashing," defined as "a strategy that organizations adopt to engage in misleading behavior about ethical AI/algorithmic systems" (p. 1128). Their model identifies the same exploitation of information asymmetry that characterizes greenwashing, applied specifically to algorithmic operations.

The concept gained regulatory teeth when the U.S. Securities and Exchange Commission charged two investment advisory firms with making false statements about their AI use, imposing \$400,000 in combined penalties and explicitly labeling the practice "AI washing" (U.S. SEC, 2024). In this paper, we conceptualize AI-washing as the strategic misrepresentation of AI use within customer-facing communications - encompassing both the exaggeration or fabrication of AI capabilities to project unwarranted technological sophistication (De Jong et al., 2020; U.S. SEC, 2024), and the deliberate concealment of AI use to maintain a false impression of human authorship - exploiting the information asymmetry inherent in

algorithmic systems (Seele & Schultz, 2022). It should be noted that a parallel strand of the literature uses the same term to describe organizational governance failures: the adoption of symbolic AI ethics policies without substantive reform in regulated deployment contexts (Bietti, 2020; Seele & Schultz, 2022). The present study focuses exclusively on the consumer-facing dimension of this misrepresentation.

2.2 The Psychology of Trust and Signaling

The psychological impact of AI-washing is understood through four interconnected theoretical lenses: organizational trust, machine agency perception, signaling theory, and brand authenticity.

Trust. Following Mayer et al. (1995), we understand trust as the willingness to accept vulnerability based on positive expectations. Colquitt et al. (2007) demonstrate that this willingness relies on three distinct dimensions of trustworthiness: ability, benevolence, and integrity. Furthermore, organizational success and competitiveness increasingly depend on maintaining a balance between interpersonal relationships and impersonal trust in the firm's systems and processes (Michalec et al., 2024). AI-washing threatens this entire framework: misrepresenting capabilities exposes a lack of actual competence, the inherent deception violates ethical principles, and the underlying strategy signals self-interest rather than genuine consumer welfare.

Machine agency. Sundar's (2020) Human-AI Interaction - Technology Is Mediating Experience (HAI-TIME) model explains how consumers process AI claims through a "machine heuristic" - a mental shortcut attributing both positive qualities (precision, objectivity) and negative ones (coldness, lack of empathy) to algorithmic systems. This creates an inherent tension for SMEs: AI labels can signal competence through automation bias (the tendency to overtrust machines) but simultaneously undermine the warmth and personal connection central to the SME's relational advantage. Moreover, algorithm aversion - the tendency to reject algorithmic systems entirely after a single observed failure (Sundar, 2020) - means that discovery of AI-washing can trigger a loss of trust.

Signaling. Signaling theory holds that effective signals must be costly to produce, ensuring only genuinely capable firms can send them (Connelly et al., 2011). Ching, Gerab, and Toste (2017) apply this framework to sustainability reporting, finding no

significant association between reporting quality and financial performance - suggesting that the signal alone is insufficient without alignment to underlying reality. In SME marketing, humanness functions as a costly signal of authenticity: human-crafted content requires time, skill, and personal investment that cannot be easily scaled. AI-washing decouples this signal from its substance, mirroring the reporting paradox identified by Ching et al. (2017) - projecting the appearance of skilled human effort in cases where the content was, in reality, produced automatically, at the push of a button.

Brand authenticity. The cumulative effect of these dynamics is captured by Morhart, Malär, Guèvremont, Girardin, and Grohmann's (2015) perceived brand authenticity (PBA) construct, comprising four dimensions: credibility (delivering on promises), integrity (genuine moral values), symbolism (identity expression), and continuity (narrative consistency). AI-washing directly undermines credibility (exaggerated claims), integrity (deception signals self-interest, paralleling Colquitt et al.'s trust dimension), and continuity (a relational brand suddenly signaling algorithmic automation). The Transparency Paradox examined in the following sections emerges from this convergence: in the short term, AI labels exploit automation bias to signal ability (Sundar, 2020), but the resulting signal-substance gap destabilizes brand authenticity (Morhart et al., 2015), and exposure triggers normative deception judgments (De Jong et al., 2020) compounded by algorithm aversion (Sundar, 2020) - producing a trust collapse disproportionate to the perceived offense.

3 Methodology

3.1 Research Design

Given the rapid development of Generative AI in SME marketing, limited empirical evidence exists that directly examines the disclosure paradox in this specific context. The latest systematic reviews on AI in marketing and Generative AI (Chan & Choi, 2025; Prasanna & Kushwaha, 2025) highlight a rapidly expanding but fragmented body of work that lacks an integrated perspective on consumer trust and authenticity. This study therefore adopts an integrative literature review methodology (Snyder, 2019) to synthesize fragmented findings across marketing, consumer psychology, and information systems. Unlike traditional narrative reviews that primarily serve as background for primary research, an integrative review treats the literature itself as data, enabling the construction of a novel conceptual

framework where primary data collection would be premature (Snyder, 2019). The primary objective is to identify recurring patterns, paradoxes, and theoretical tensions in AI disclosure strategies, ultimately linking them to dimensions of organizational trust and brand authenticity in SME contexts.

3.2 Scope and Boundaries

To ensure analytical depth, the research scope is narrowed to the intersection of SME marketing communications and consumer trust, with a focus on customer-facing interactions where source authenticity is essential for SMEs' relational competitive advantage. The analysis concentrates on three overlapping domains of customer-facing Generative AI use. The first is generative content creation - the use of large language models for copywriting, blog posts, and personalized messaging, where AI can augment or replace the human voice of the brand (Wahid et al., 2023). The second is conversational AI, specifically the deployment of chatbots and virtual assistants in customer service and conversational marketing contexts, where AI serves as the direct interface between brand and consumer (Israfilzade & Sadili, 2024). The third is attribution and authorship claims - the strategic use or omission of labels such as "AI-powered" or "Human-made" in marketing collateral, and the misrepresentation of human versus AI authorship in brand communications (Kirk & Givi, 2025). The review explicitly excludes technical performance evaluations of AI models (e.g., accuracy, latency, model architectures), internal operational AI applications (e.g., HR automation, inventory optimization) that do not directly affect consumer perception, and B2B procurement and supply-chain analyses where end-consumer trust is only indirectly involved.

3.3 Literature Search and Selection

A systematic search was conducted in Scopus, Web of Science, and Google Scholar covering the period from January 2020 to December 2025 for literature specifically addressing Generative AI, algorithm aversion, and algorithmic disclosure. Meanwhile, foundational theories regarding organizational trust, signaling theory, and corporate washing phenomena were drawn from seminal literature without date restrictions. The search strategy employed keyword combinations such as: ("AI disclosure" OR "algorithm aversion" OR "AI transparency" OR "generative AI") AND ("consumer trust" OR "brand authenticity" OR "transparency paradox") AND ("SME" OR "small business" OR "small enterprise"). Additional targeted

searches were performed for key constructs including “Word-of-Machine effect”, “AI-washing”, and “ethics washing” to capture adjacent literatures on automated agency, moral disgust, and deceptive signaling. Inclusion criteria were: (1) peer-reviewed empirical or conceptual papers, (2) focus on customer-facing AI contexts where source authenticity is salient, (3) outcomes related to trust, authenticity, moral evaluation, or consumer perception, and (4) English language. Exclusion criteria eliminated: (1) purely technical AI performance studies, (2) internal, non-customer-facing AI use cases, and (3) studies focused exclusively on large enterprises without SME-relevant implications. The search yielded 42 relevant papers after screening, supplemented by regulatory and policy documents (e.g., EU AI Act) and seminal theoretical contributions on Signaling Theory and organizational trust.

3.4 Data Extraction, Theoretical Lens, and Analysis

Data extraction and thematic synthesis followed the integrative review protocol outlined by Snyder (2019). Each included source was systematically coded along four dimensions: (1) AI disclosure strategy (explicit labeling, concealment, partial or conditional transparency), (2) affected trust dimensions, applying Colquitt et al.'s (2007) framework, (3) contextual factors (hedonic vs. utilitarian consumption, SME vs. large-firm setting, type of AI application), and (4) observed outcomes (changes in perceived authenticity, consumer response, reputational or regulatory risk). A multi-theoretical lens guided the synthesis. Signaling Theory was employed to interpret AI labels (or their absence) as market signals of quality and authenticity, building on prior work in sustainability reporting and authentic communication (Ching et al., 2017; Morhart et al., 2015) to explain why SMEs might engage in deceptive signaling (“washing”). By integrating these signaling dynamics with Colquitt’s trust dimensions, the analysis illuminated specific contexts where an intended signal of efficiency conflicts with a perceived signal of inauthenticity. Subsequent cross-case comparative analysis identified convergent and divergent findings across studies, yielding three dominant thematic clusters: the Transparency Paradox, the Word-of-Machine Effect, and the Personalization Paradox. Ultimately, the resulting empirical patterns were theoretically integrated into the proposed “Artificial Authenticity” framework, connecting AI-washing and disclosure strategies to brand authenticity in SME marketing.

4 Results (The Paradoxes)

The following three sections examine the conditions under which AI use in SME marketing communications undermines, rather than increases, perceived authenticity and trust. The synthesized literature reveals three vulnerabilities based on the authorship of the message (the Transparency Paradox), the context of the message (the Word-of-Machine effect), and the depth of profiling behind the message (the Personalization Paradox).

Table 1: Summary of AI-Integration Vulnerabilities in SME Marketing

Paradox / Vulnerability	Core Mechanism	Impact on SME Marketing	Key Literature
Transparency Paradox	Disclosing AI authorship reduces perceived authenticity; concealing it leads to trust collapse upon exposure.	Creates a double bind where both proactive disclosure and reactive exposure erode relational authenticity.	Delmas & Burbano (2011); Morhart et al. (2015); Wagner (2019); Bietti (2020); Luo et al. (2019); Seele & Schultz (2022); Brüns & Meißner (2024); U.S. SEC (2024); Kirk & Givi (2025); Koning & Voorveld (2025)
Word-of-Machine Effect	Consumers systematically discount AI recommendations in hedonic, symbolic, or identity-relevant contexts.	Penalizes SMEs for using AI in affective categories where emotional resonance and human effort are essential.	Castelo et al. (2019); Sundar (2020); Longoni & Cian (2020); Granulo et al. (2021); Bellaiche et al. (2023)
Personalization Paradox	Scalable personalization mimics intimate knowledge but crosses into intrusiveness and feelings of surveillance.	Deep algorithmic profiling degrades perceived benevolence, converting relational advantage into strategic exploitation.	Mayer et al. (1995); Colquitt et al. (2007); Aguirre et al. (2015); Lefkeli et al. (2023); Abrokwhah-Larbi (2023); Hennighausen et al. (2025)
Strategic Solutions (Artificial Authenticity)	Utilizing Human-in-the-Loop (HITL) integration and transparent signaling to mitigate algorithm aversion.	Restores relational proximity and trust, allowing SMEs to leverage AI efficiency without sacrificing authenticity.	Connelly et al. (2011); Rajaram & Tinguely (2024); Haupt et al. (2024); Sarker et al. (2025)

While Section 2.1 already addressed RQ1 by establishing the conceptualization of AI-washing, these three vulnerabilities directly correspond to the paper's remaining research questions: the Transparency Paradox addresses RQ2 by examining how AI disclosure manifests in SME marketing; the Word-of-Machine effect further elaborates RQ2 by delineating the contextual boundaries of algorithm aversion; and the Personalization Paradox rounds out RQ2 by identifying the third dimension of the structural trap. Collectively, the 'Artificial Authenticity' framework proposed in Section 5 responds to RQ3.

Table 1 synthesizes the three core vulnerabilities associated with AI integration in SME marketing and outlines 'Artificial Authenticity' as a strategic solution to mitigate these algorithmic aversions.

4.1 The Transparency Paradox (RQ2)

The Transparency Paradox describes a structural dilemma in which both disclosure and non-disclosure of AI use in marketing communications can erode consumer trust - leaving SMEs with no straightforwardly safe option. Disclosing AI authorship can reduce the perceived authenticity of a message and trigger negative consumer responses (Kirk & Givi, 2025); yet concealing AI use constitutes a form of deception that, once uncovered, causes equal or greater reputational damage (Luo et al., 2019; Kirk & Givi, 2025). To illustrate: consider a local artisan bakery that uses a generative AI tool to write its weekly newsletter to loyal customers. If the bakery discloses that its warm, personally addressed messages were AI-generated, subscribers may feel the emotional connection was simulated. Conversely, if the bakery omits this information and AI involvement is later revealed - through a journalist's investigation, a regulatory audit, or mandatory labeling under the EU AI Act - customers may interpret the prior silence as deliberate dishonesty, damaging the relationship more severely than the original disclosure would have. This double bind is the Transparency Paradox.

To understand the mechanics of this paradox, it is necessary to examine how the act of disclosure itself triggers consumer backlash. Developing work on generative AI in marketing shows that disclosure of AI use is far from a simple "more transparency is always better" story for firms. Across seven preregistered experiments, Kirk and Givi (2025) demonstrate a robust "AI-authorship effect": when consumers believe

that emotional marketing communications are written by an AI rather than a human, they perceive the message as less authentic, experience greater moral disgust, generate less positive word of mouth (PWOM), and show lower customer loyalty.

However, this effect applies specifically to emotional content; it is attenuated when the communication is factual, when AI only edits rather than authors the message, when the AI signs the communication directly, and when consumers believe that most marketers already use AI. In other words, disclosure that an emotional message is AI-written reliably hurts authenticity and downstream behavioural responses, whereas disclosure in purely factual contexts may be comparatively harmless.

At the same time, regulatory and ethical pressures increasingly push firms toward more transparency. Kirk and Givi (2025) document how legislators and regulators (e.g., the EU AI Act) begin to require clear AI labels for generative AI communications, while consumers themselves express a desire for transparency about AI use in marketing. This aligns with Rai's (2020) commentary on "explainable AI", which frames the core challenge as a move from "black box" to "glass box" systems: explanations and disclosures are needed to build trust, expose biases, and meet fairness and accountability requirements, especially in high-stakes domains. Explainability and disclosure, however, can also surface the very aspects of AI decision-making that users find normatively troubling, thereby reducing trust and acceptance rather than enhancing it.

When applied to emotional marketing, this means that making the AI visible can both satisfy an ethical/regulatory requirement and trigger a negative authenticity judgement. The paradox for SMEs follows directly: if an SME openly discloses that its emotional communications are AI-generated, the AI-authorship effect predicts lower perceived authenticity, increased moral disgust, and reduced PWOM and loyalty. Yet if the same SME conceals AI use, and this use is later revealed through regulation, media exposure, or improved AI-detection tools, consumers interpret the previous non-disclosure as dishonesty, again eliciting moral disgust and avoidance responses. This creates a "transparency paradox": transparency about AI use in emotional communications undermines authenticity by revealing the machine author, whereas non-transparency undermines authenticity once hidden AI use is uncovered.

Evidence from adjacent AI-disclosure contexts reinforces this dilemma. Luo et al. (2019) show in an e-commerce experiment that when customers are made aware that they are interacting with an AI chatbot rather than a human operator, their purchase likelihood decreases, even though the functional performance of the chatbot may be adequate. Disclosing machine involvement suppresses conversion in a commercial setting.

SMEs face a double bind: they cannot safely hide AI use, but they also cannot straightforwardly signal it without incurring authenticity and trust penalties when communications are emotional, relational, or identity-relevant. Both proactive disclosure and reactive exposure erode consumer trust in emotional marketing contexts, rendering conventional disclosure mechanisms insufficient in relational communication.

4.2 The Word-of-Machine Effect

A second, closely related paradox arises when considering not only who is disclosed as the author, but what kind of advice or content AI is perceived to provide. Longoni & Cian (2020) introduce the “word-of-machine” effect by contrasting AI advice with traditional “word-of-mouth”. In multiple studies, they show that consumers systematically discount recommendations when they believe they come from an AI rather than a human, even when the informational content is held constant. This AI aversion is strongly context-dependent: AI is more accepted in utilitarian, functional decision domains (e.g., where accuracy and efficiency are paramount), but is resisted in hedonic domains, where consumers seek identity-relevant or emotionally rich benefits. The central role of these settings is further emphasized in retail environments, where pleasure-driven shopping motivation - driven by the pursuit of experiential and sensorial stimuli (Tyrväinen et al., 2020) - is a primary catalyst for driving positive emotional and cognitive customer experiences. Because creating an enjoyable and entertaining shopping environment is key to generating authentic word-of-mouth and long-term customer loyalty (Tyrväinen et al., 2020), replacing human touchpoints with algorithmic communication in these contexts threatens the core mechanism of brand connection. In such affective categories, AI advice feels less appropriate and less trustworthy, leading to lower compliance, lower choice share, and more negative affective responses compared to human advice.

Huang and Rust (2021) provide a strategic framework that helps position this effect in a broader AI-in-marketing landscape. They distinguish “mechanical”, “thinking” and “feeling” AI, and argue that content creation for marketing communications increasingly sits in the intersection of thinking and feeling AI: it requires balancing data-driven optimization with emotional resonance and relationship-building. Their framework also reviews evidence that consumers resist AI in domains where identity, intimacy and emotional exchange are central - for example, in medical decisions, identity-laden consumption, and anthropomorphised service robots in symbolic consumption contexts. This aligns with Longoni & Cian’s (2020) finding that the very contexts in which emotional content is most valuable (hedonic and symbolic) are precisely those where “word-of-machine” is least acceptable.

The reluctance to accept AI-generated or AI-recommended experiential content generalises beyond classic marketing settings into aesthetic domains. Bellaiche et al. (2023) examine how people evaluate artworks that are in fact all created by AI, but are randomly labelled as “human-created” or “AI-created”. In two large-sample, within-subjects studies, they find that artworks labelled as human-created receive higher ratings on liking, beauty, profundity, and perceived worth than identical artworks labelled as AI-created. Additional measures reveal that the human label increases perceived narrativity (story), effort, and meaning, and that these more “communicative” judgements mediate the label effect for deeper evaluations such as profundity and worth. In other words, knowing (or believing) that a human created a piece makes it feel more effortful, meaningful and narrative-rich, even when the sensory stimulus is unchanged. Consistent with the marketing evidence, consumers in these symbolic contexts value not only what is said or shown, but the perceived human experience behind it.

Related work on algorithm aversion and preferences for human versus automated labour further clarifies when and why “word-of-machine” is problematic for marketers. Castelo et al. (2019) show that aversion to algorithms is task-dependent: consumers are more willing to rely on algorithms for tasks that are objective, quantifiable and impersonal, and are more reluctant when tasks require intuition, moral judgement or an understanding of human uniqueness. Granulo et al. (2021) find that preferences for human labour over robotic labour are particularly strong in symbolic consumption contexts - situations where products and services serve as identity signals or carriers of meaning, rather than purely functional solutions. When marketing communications are framed as human, symbolic, or morally laden acts

(e.g., expressing gratitude, pride, sympathy, or inspiration), consumers systematically devalue AI involvement.

The devaluation of AI involvement in symbolic contexts stems from a perceived lack of human effort and narrative depth. Bellaiche et al. (2023) demonstrate that human-authored labels increase the perceived meaning and profundity of a message, elements that algorithms cannot replicate. This evidence grounds Longoni and Cian's (2020) word-of-machine effect in Huang and Rust's (2021) framework: the penalty for AI is highest when it acts as a 'feeling' agent. Attempting to emulate relational warmth triggers expectations of internal states that machines inherently lack, transforming authentic engagement into a devalued output even when the content quality remains identical.

4.3 The Personalization Paradox and the Convergence of Vulnerabilities

While the Transparency Paradox concerns the act of disclosure (who authored the content) and the Word-of-Machine effect dictates the contextual boundaries (hedonic vs. utilitarian), a third distinct vulnerability manifests regarding the depth of profiling: the Personalization Paradox. Generative AI promises SMEs scalable personalization, yet this creates a backlash when personalization becomes "too good" and crosses into intrusiveness.

This paradox operates through a different mechanism than transparency. While the Transparency Paradox damages trust because the firm outsourced its voice to a machine, the Personalization Paradox damages trust because the machine appears to know too much, triggering feelings of vulnerability. As Aguirre et al. (2015) established, highly tailored content backfires when consumers infer covert data collection, shifting their perception from being "understood" (relational proximity) to being "surveilled" (exploitation).

For SMEs, this tension is particularly dangerous. Abrokwah-Larbi (2023) posits that generative AI, fueled by deep learning and smart data, enables real-time, context-oriented personalization at scale. Firms increasingly rely on such deep personalization to drive user engagement in highly interactive digital environments, which often yield stronger consumer responses than traditional formats (Szeberényi et al., 2025). However, when an SME uses GAI to mimic intimate customer knowledge, it risks converting its relational advantage into a perceived instrument of

surveillance. Hennighausen et al. (2025) demonstrate that when AI-mediated communication is recognized in personalized contexts, it specifically degrades perceived benevolence and integrity; customers infer that the artificial intimacy is driven by strategic efficiency rather than genuine care. These three vulnerabilities converge to form a strict strategic trap. When SMEs combine deep algorithmic profiling with emotional or hedonic messaging, any subsequent disclosure of AI authorship actively dismantles the very relational authenticity the firm attempted to scale.

5 Discussion

Building on the paradoxes identified in Section 4, this discussion proposes 'Artificial Authenticity' as a strategic framework for SMEs navigating the transparency dilemma.

The integration of Generative AI into SME marketing disrupts the relational trust mechanisms on which these firms have traditionally relied, by introducing a trade-off between operational scaling and perceived source authenticity.

5.1 The Trust Implications of AI-Washing (RQ1)

Viewed through foundational theories of organizational behavior, 'AI-washing' fundamentally undermines consumer trust in SME marketing. Based on Colquitt et al.'s (2007) framework, AI-washing simultaneously threatens all core dimensions of organizational trust. Maintaining the false appearance of personal human effort - when, in reality, an AI is doing the work - not only reveals the absence of genuine professional investment and exposes a lack of true competence, but the accompanying misrepresentation violates ethical integrity and reflects the firm's self-interest rather than genuine consumer welfare. Furthermore, based on Sundar's (2020) machine agency framework, algorithm aversion triggers a severe loss of trust upon the discovery of such deception. As a consequence, the signal-substance gap inherent in AI-washing directly destabilizes perceived brand authenticity by undermining the firm's credibility, integrity and narrative continuity (Morhart et al., 2015).

5.2 The Transparency Paradox, Word-of-Machine, and Personalization (RQ2)

The integration of generative AI into SME marketing creates a severe double bind that transcends mere regulatory compliance. Applying Signaling Theory, the convergence of the Transparency Paradox, the Word-of-Machine effect, and the Personalization Paradox creates a structural trap that conventional disclosure mechanisms cannot resolve. When an SME uses generative AI to create highly personalized, emotionally resonant content, it aims to maximize the relational signal; however, it simultaneously maximizes the risk of consumer backlash. If the SME explicitly discloses this AI usage, it triggers the "AI-authorship effect" (Kirk & Givi, 2025), where the disclosure immediately strips the message of its perceived authenticity. This is further compounded by the "Word-of-Machine" effect (Longoni & Cian, 2020), as consumers tend to devalue AI-generated content in the very emotional and experiential contexts that SMEs rely on for differentiation.

Conversely, if the firm conceals the AI to maintain the illusion of a personal touch, it engages in AI-washing, risking a total collapse of trust upon exposure. This tension is greatly exacerbated by the Personalization Paradox. While AI enables mass personalization, the explicit recognition of algorithmic profiling shifts the consumer's perception from being relationally "understood" to being strategically "surveilled" (Hennighausen et al., 2025). Conventional transparency mechanisms fail SMEs in affective and deeply personal contexts. To address this impasse, this study proposes 'Artificial Authenticity' as a strategic framework. This approach shifts the firm's focus from declaring what the machine generated to demonstrating how human expertise guided the process, mitigating the authenticity costs associated with algorithmic communication.

Figure 1 summarizes the mechanism through which both disclosure and concealment lead to a loss of consumer trust, and illustrates how the Artificial Authenticity strategy resolves this structural trap.

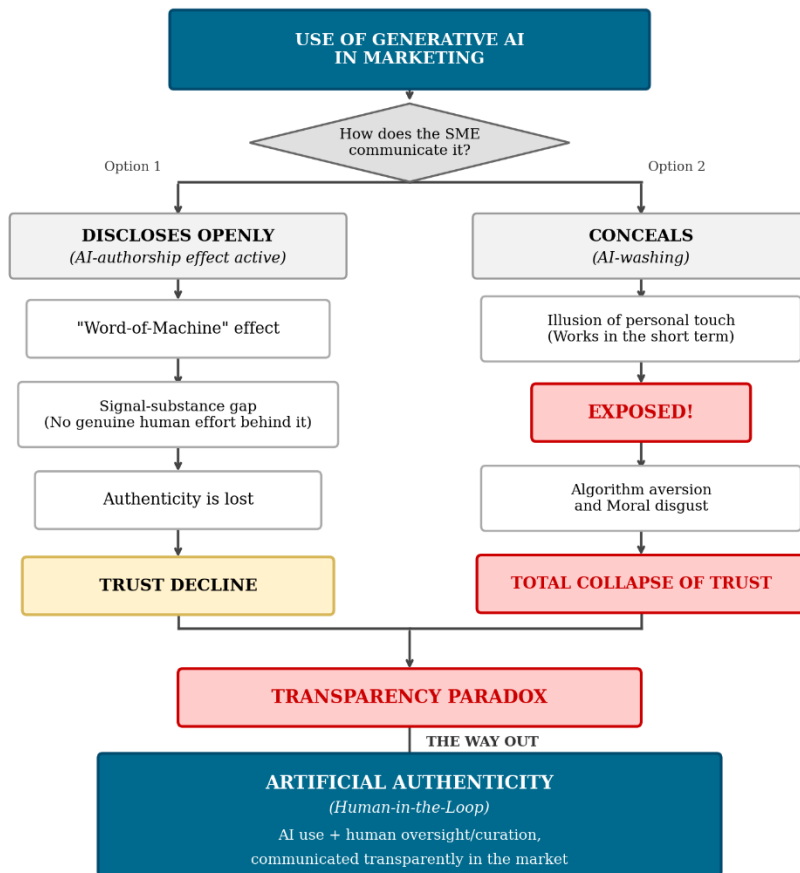


Figure 1: The Transparency Paradox and the Artificial Authenticity Framework
Source: Authors' own compilation

5.3 Restoring Brand Authenticity through Human-in-the-Loop (RQ3)

To address the Transparency Paradox and the Word-of-Machine effect (RQ3), SMEs should adopt 'Artificial Authenticity'-a strategy centered on human-in-the-loop (HITL) integration. AI integration yields the strongest outcomes when it augments human oversight rather than substituting for it (Davenport et al., 2020). Fully autonomous operations can diminish perceived responsibility and impair trust by heightening a sense of consumer exploitation (Lefkeli et al., 2023).

Empirical evidence confirms that human-AI collaboration alleviates negative consumer responses when the firm indicates explicit human control (Haupt et al., 2024). By demonstrating that human experts guide and validate AI-assisted content, SMEs can leverage generative efficiency while maintaining the empathy and ethical oversight required for relational proximity (Ismail et al., 2025).

To illustrate how this resolves the tension outlined in Section 4.1, we return to the artisan bakery example. If the bakery relies on a binary compliance label (e.g., *"This newsletter was generated by AI"*), it triggers the AI-authorship effect, stripping the message of its emotional resonance. Conversely, completely concealing the tool risks AI-washing and subsequent trust collapse. By applying the Artificial Authenticity framework, the bakery shifts the disclosure focus from the machine's autonomous output to the human's curation process. A strategic disclosure such as, *"Drafted with AI assistance, but carefully curated and approved by our head baker,"* explicitly signals human-in-the-loop oversight. This nuanced reframing satisfies ethical transparency requirements while demonstrating the narrative effort and relational warmth that define the SME's competitive advantage.

6 Conclusions

6.1 Theoretical and Practical Contributions

This research demonstrates that the adoption of Generative AI forces SMEs into a fundamental dilemma: prioritizing operational efficiency directly threatens the relational proximity that forms their core competitive advantage. Our synthesis indicates that converging vulnerabilities - the Transparency Paradox, the Word-of-Machine effect, and the Personalization Paradox - render binary disclosure methods inadequate in emotional and symbolic contexts.

Beyond individual firm strategies, Artificial Authenticity informs both marketing practice and regulatory policy. As policymakers and digital platforms increasingly mandate algorithmic transparency (e.g., the EU AI Act), strict compliance inadvertently punishes SMEs by stripping their communications of perceived genuineness. Therefore, industry standards and future regulations must evolve to recognize and accommodate collaborative human-AI authorship, rather than enforcing a reductionist, binary "human versus machine" labeling system.

6.2 Limitations and Future Research

This study is limited by its reliance on cross-contextual inference in the absence of SME-specific primary data; the integrative review methodology, while appropriate given the fragmented state of the field, cannot substitute for experimental or longitudinal validation of the proposed Artificial Authenticity framework.

Ultimately, consumer trust in an era of AI-mediated communication is not built by pretending the machine does not exist, nor by allowing it to operate unchecked, but by transparently showcasing the human expertise that guides it. Future empirical research should focus on testing the boundary conditions of these collaborative signaling strategies across different sectors and regulatory environments to further refine the governance of algorithmic communication.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Google Gemini for structuring the manuscript, Gemini and Perplexity Pro to assist in integrating sources into the text, and Claude AI for structural review and critical feedback. After using these tools, the author(s) thoroughly reviewed and edited the content as needed and take(s) full responsibility for the final content and integrity of the publication.

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CAN ALGORITHMS BE TRUSTED? CONSUMER TRUST AND LOYALTY IN AI-GENERATED BRAND COMMUNICATION

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This study systematically examines how generative artificial intelligence (AI) in brand communication, such as AI-generated social media content, marketing copy, chatbots, and virtual influencers, affects consumer trust and loyalty. Following PRISMA guidelines, a structured literature search was conducted in Scopus and Web of Science. After deduplication and screening, 165 peer-reviewed articles were included in the final analysis. Using thematic categorization, studies were grouped by AI application and trust-related constructs to identify dominant mechanisms and moderators. The findings indicate that AI-mediated communication can both enhance and undermine consumer trust. Competence-based trust is frequently observed in chatbot interactions, whereas generative AI content and AI influencers produce more conditional effects shaped by disclosure, perceived authenticity, anthropomorphism, and cultural context. Despite increased engagement, undisclosed or misaligned AI use may weaken credibility and long-term loyalty. The review highlights conceptual fragmentation and limited longitudinal evidence, proposing a conditional trust formation framework to guide future research on AI-mediated consumer–brand relationships.

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1 Introduction

Artificial intelligence (AI) has rapidly transformed the landscape of brand communication. From conversational chatbots and automated customer service agents to generative AI content creation and virtual influencers, AI systems increasingly mediate interactions between brands and consumers across traditional and immersive digital environments, such as the metaverse (Kirkby et al., 2025; Szeberényi et al., 2025). These developments raise fundamental questions about trust formation in digitally mediated environments. While AI technologies promise efficiency, scalability, and personalization, their non-human nature introduces potential risks related to authenticity, transparency, and credibility (Erickson, 2026).

Despite the rapidly expanding body of literature, the field remains theoretically fragmented. This fragmentation reflects broader challenges in academic measurement, where evaluating complex strategic impacts – such as the effects of integrated corporate reporting (Katherine et al., 2025) – or creating composite indicators to rank performance remains a non-trivial task (Kozma et al., 2021). Trust, authenticity, engagement, and credibility are frequently examined in isolation, while AI applications, such as chatbots, generative content, and virtual influencers, are often studied separately, limiting an integrative understanding. Moreover, the mechanisms through which AI disclosure, perceived authenticity, and cultural context shape trust outcomes remain dispersed across disciplinary silos, and evidence on long-term brand loyalty formation is particularly scarce.

To address these gaps, the present study conducts a systematic literature review (SLR) of 165 peer-reviewed articles examining AI-mediated brand communication and trust-related constructs. The objective is to synthesize existing findings, identify dominant mechanisms and moderators, and outline a conditional framework of AI-based trust formation. By integrating dispersed research streams, this study addresses the following research questions:

- RQ1: How do different types of AI-mediated brand communication (chatbots, generative content, and virtual influencers) differentially influence dimensions of consumer trust?

- RQ2: What are the primary mechanisms and moderators (e.g., disclosure, authenticity, and culture) that determine whether AI-driven branding enhances or undermines consumer credibility?
- RQ3: What empirical evidence exists regarding the impact of AI-mediated communication on long-term brand loyalty?

Through this systematic approach, the study provides a structured foundation for future theoretical development and empirical investigation, particularly regarding cross-cultural validation and long-term consumer-brand relationships.

2 Theoretical Background

2.1 AI-mediated brand communication

The rapid advancement of artificial intelligence – driven by complex predictive models increasingly utilized across diverse business and financial sectors (Gunapriya et al., 2025) – has transformed brand communication from human-generated messaging to algorithmically mediated interaction. AI-driven applications, such as generative AI, are increasingly employed to craft diverse marketing content, ranging from social media posts to virtual influencer campaigns, thereby altering the traditional landscape of consumer-brand engagement (Brüns & Meißner, 2024; Hewapathirana & Perera, 2024; Venkateswaran et al., 2024; Wang et al., 2025). This burgeoning field necessitates a robust understanding of how consumers perceive and respond to such technologically mediated communication, particularly concerning trust and loyalty (Panda et al., 2025). Unlike traditional automation, generative AI produces content that mimics human creativity and social presence, thereby reshaping perceptions of authenticity and credibility.

This shift introduces a paradoxical dynamic where AI-generated content can be perceived as more trustworthy and objective in certain contexts, yet human-authored content often remains preferred despite AI's objective superiority in specific metrics (Kirkby et al., 2023). Indeed, recent empirical evidence suggests that while generative AI holds considerable potential for enhancing marketing content, its impact on consumer behavior remains a complex area, often inducing negative attitudinal and behavioral reactions among followers when its use is disclosed (Brüns & Meißner, 2024).

Research on AI-generated content demonstrates that perceived realism and contextual alignment significantly influence consumer evaluations of brand messages. Studies examining AI-generated imagery and advertising copy suggest that realism can enhance persuasive impact, yet may simultaneously trigger skepticism when artificial origins are detected (Israfilzade, 2025). Similarly, chatbot research highlights the growing integration of AI into frontline service interactions, where anthropomorphic design and conversational responsiveness shape relational perceptions (Kim, 2025).

Within influencer marketing, AI-driven virtual influencers represent a further evolution. Comparative research indicates that AI influencers can cultivate parasocial relationships and, in some contexts, generate levels of credibility comparable to or exceeding those of human influencers. However, the mechanisms underlying these effects differ, as human influencers rely more heavily on narrative depth and cultural resonance, whereas AI influencers often benefit from perceived technological novelty and consistency (Cokki & Hazain, 2025).

2.2 Consumer trust in AI contexts

Consumer trust is widely conceptualized as the willingness to rely on a brand or communication source under conditions of uncertainty. In AI-mediated environments, uncertainty increases due to reduced human agency, opacity of algorithms, and concerns about authenticity (Pan, 2025).

Across chatbot and AI communication studies, trust is frequently examined through perceived competence, reliability, and integrity (Newen et al., 2025). Empirical findings suggest that AI can enhance trust when performance accuracy and responsiveness are salient. However, the absence of transparency or misalignment between AI-generated content and brand identity may undermine perceived credibility (Patel & Dada, 2025).

Influencer-focused studies further demonstrate that trust in AI agents is closely linked to perceived authenticity and social presence (Patel & Dada, 2025). Parasocial Interaction Theory explains how emotional bonds can form even with non-human agents, while Source Credibility Theory suggests that expertise and trustworthiness cues remain central, regardless of whether the source is human or artificial. These

findings indicate that trust formation in AI contexts is not binary but conditional and context-dependent (Chen et al., 2026).

2.3 The role of disclosure and transparency

A central theoretical tension in AI-mediated communication concerns disclosure. Transparency regarding AI authorship can function both as a trust-building mechanism and as a trigger of skepticism. Studies manipulating AI disclosure reveal mixed outcomes: while explicit identification of AI involvement may enhance perceptions of honesty and ethical integrity, it can also reduce perceived authenticity and emotional connection (Morosoli et al., 2025).

The transparency dilemma in AI-mediated communication is illuminated by two key theoretical frameworks. Signaling Theory views AI disclosure as a credible signal of corporate honesty and ethical integrity, thereby promoting initial trust formation. In contrast, the Persuasion Knowledge Model frames these disclosures as "persuasion cues" that arouse consumer skepticism: awareness of machine-generated content activates persuasion knowledge, prompting perceptions of the brand's transparency efforts as manipulative tactics rather than sincere engagement. Consequently, this triggers a "backfire effect," where intended trust-building measures instead diminish perceptions of emotional warmth and human-like authenticity (Qiu et al., 2025).

From a Stimulus–Organism–Response (S-O-R) perspective, AI disclosure operates as a stimulus that shapes cognitive and affective responses, ultimately influencing behavioral intentions. Similarly, anthropomorphism theory suggests that human-like cues can mitigate the psychological distance between consumers and AI agents, potentially offsetting negative disclosure effects (Lu et al., 2025).

Emerging research, therefore, conceptualizes trust in AI-driven brand communication as conditional on moderating variables, including transparency strategies, anthropomorphic design, cultural context, and consumer AI literacy.

2.4 Toward a conditional trust formation framework

Synthesizing the dominant theoretical perspectives, existing research indicates that AI does not inherently increase or decrease trust. Instead, trust outcomes depend on the interaction between AI type, communicative transparency, perceived

authenticity, and contextual factors (Krüeger et al., 2025). Chatbots often generate positive trust effects in service settings, generative AI content produces mixed results depending on disclosure and realism, and AI influencers demonstrate culturally contingent credibility pathways (Wang et al., 2026).

This fragmented yet converging body of literature suggests the need for an integrative framework that conceptualizes trust formation in AI-mediated brand communication as a conditional process rather than a direct technological effect.

2.5 Operational definitions of key constructs

To resolve the conceptual fragmentation identified in current AI research, it is essential to establish precise boundaries between the core constructs examined in this study. The following table provides operational definitions for trust, authenticity, credibility, and engagement, clarifying their specific roles within the context of AI-mediated brand communication.

Table 1: Key constructs definitions

Construct	Operational Definition in AI Context
Trust	The consumer's willingness to rely on a brand or AI agent (e.g., chatbot) under conditions of uncertainty, based on perceptions of competence, reliability, and integrity.
Authenticity	The degree to which AI-generated content or a virtual influencer is perceived as genuine, sincere, and consistent with the brand's established identity.
Credibility	The perceived expertise and trustworthiness of the communication source, determining whether the consumer accepts the AI-driven message as truthful.
Engagement	The level of cognitive, affective, and behavioral involvement a consumer has with AI-mediated brand touchpoints, such as social media interactions or chatbot usage.

Source: Authors' own edit

3 Methodology

This study employs a systematic literature review (SLR) design to synthesize existing research on the effects of artificial intelligence (AI)-driven brand communication on consumer trust and loyalty. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, replicability, and methodological rigor.

3.1 Search strategy and data collection

A comprehensive search was conducted in two major academic databases: Scopus and Web of Science. These databases were selected due to their multidisciplinary coverage and strong representation of marketing, communication, and technology-related journals. The search strategy combined keywords related to artificial intelligence (e.g., “generative AI,” “chatbot,” “virtual influencer,” “AI-generated content,” “predictive analytics”) with terms associated with consumer trust and brand communication (e.g., “trust,” “credibility,” “authenticity,” “brand loyalty,” “consumer engagement”).

In Scopus, the following Boolean search string was used, which resulted in 285 articles:

```
TITLE-ABS-KEY (( "generative AI" OR "AI-generated content" OR "AI influencer*" OR "chatbot*" OR "AI" OR "artificial intelligence" ) AND ( "trust" OR "consumer trust" OR "customer trust" OR "user trust" OR "perception" OR "authenticity" ) AND ( "loyalty" OR "consumer loyalty" OR "customer loyalty" OR "brand loyalty" OR "engagement" ) AND ( "brand communication" OR "marketing" OR "social media" OR "advertising" OR "digital communication" ))
```

Web of Science search with the below string earned 385 publications after filtering to Articles only.

```
TS= (("generative AI" OR "AI-generated content" OR "AI influencer*" OR chatbot* OR "artificial intelligence" OR AI) AND (trust OR "consumer trust" OR "customer trust" OR "user trust" OR perception OR authenticity) AND ("brand loyalty" OR "consumer loyalty" OR "customer loyalty" OR loyalty OR engagement) AND ("brand communication" OR marketing OR "social media" OR advertising OR "digital communication")) AND DT=(Article) AND LA=(English)
```

Only peer-reviewed journal articles published in English were included. No strict lower time boundary was applied; however, the majority of relevant studies were published after 2018, reflecting the rapid development of generative AI technologies.

The initial database search yielded 475 records after removing duplicates. Then titles and abstracts were screened for relevance. Studies were excluded if they (1) focused solely on technical AI development without consumer-related outcomes, (2) examined AI applications unrelated to brand communication, or (3) did not address trust, credibility, authenticity, or closely related constructs. Following the screening process, 177 articles met the inclusion criteria. After further refinement and removal of clearly out-of-scope studies, 165 articles were retained for final analysis.

3.2 Data coding and thematic categorization

Given the interdisciplinary and conceptually fragmented nature of AI research, a structured thematic coding approach was applied. Each article was categorized based on its primary AI application and its focus on trust-related outcomes.

The coding framework included:

- Type of AI application (e.g., chatbot, generative content, virtual influencer, general AI communication)
- Presence and direction of trust-related outcomes (positive, negative, mixed, or not directly measured)
- Consideration of AI disclosure or transparency
- Research method (e.g., experiment, survey, content analysis, mixed-method)

Based on this structured classification, the final sample of 165 articles was organized into thematic clusters reflecting dominant research streams in AI-mediated brand communication.

3.3 Analytical approach

The review adopted a qualitative thematic synthesis combined with descriptive quantitative mapping. First, articles were grouped into major thematic categories according to AI type and trust focus. Second, patterns were identified regarding the direction of trust effects and the moderating role of disclosure, authenticity, anthropomorphism, and cultural context.

Rather than conducting a meta-analysis, the study aims to develop an integrative conceptual understanding of conditional trust formation in AI-driven brand communication. Within each thematic cluster, representative exemplar studies were selected for deeper analytical discussion based on theoretical clarity and direct measurement of trust-related constructs.

Table 2 summarizes the final categorization of the included studies:

Table 2: Final Categorization of Articles

Category	Number of Articles	Core trust focus	Role in Analysis
AI Communication Engagement Focus	48	Indirect	Mechanism support
AI Communication & Trust (General)	38	Direct	Core synthesis
Generative AI Content & Trust	22	Direct	Core synthesis
Chatbots & Trust	20	Direct	Core synthesis
AI Influencers, Engagement/Authenticity	16	Indirect	Supporting evidence
AI Influencers & Trust	14	Direct	Core synthesis
Predictive Analytics / Personalization	5	Limited	Contextual background
Ethics/ Governance Focus	2	Contextual	Transparency discussion

Source: Authors' own edit

4 Results and Discussion

To address the research questions, findings are structured according to AI type, moderating mechanisms, and loyalty-related outcomes.

4.1 RQ1: Differential trust effects across AI types

The literature reveals that different AI-mediated communication formats influence consumer trust through distinct pathways.

Chatbots and conversational agents primarily foster competence-based trust. Studies consistently show that responsiveness, accuracy, and problem-solving ability enhance perceptions of reliability and expertise. Anthropomorphic cues strengthen social presence but are secondary to performance effectiveness.

Generative AI content produces more conditional effects. High realism and brand congruence may enhance credibility; however, explicit AI disclosure often reduces perceived authenticity and emotional warmth. Trust outcomes in this category are therefore strongly authenticity-dependent.

Virtual influencers generate trust through parasocial interaction and perceived social presence. Compared to human influencers, AI influencers benefit from novelty and consistency but may lack perceived experiential authenticity. Cultural context significantly moderates these effects.

Overall, AI type matters. Trust formation mechanisms differ substantially between functional service AI and symbolic content-generating AI.

4.2 RQ2: Mechanisms and moderators of trust outcomes

A cross-stream synthesis of the reviewed literature reveals that the impact of artificial intelligence on brand trust is not technologically deterministic; rather, trust is a conditionally constructed outcome shaped by specific communicative and contextual moderators. In this context, the balance between personal and impersonal trust becomes a critical success factor for organizations, as systemic trust directly enhances consumer commitment and competitiveness (Michalec et al., 2024). The analysis identifies four primary moderating variables that dictate the direction and strength of trust outcomes.

Regarding transparency and AI disclosure strategies, on one hand, disclosure operates as a critical cognitive stimulus that shapes perceptions of ethical integrity. While transparency regarding AI authorship often bolsters perceptions of brand honesty, it frequently introduces a "transparency dilemma" by inadvertently reducing perceived emotional warmth and human-like authenticity. This risk of perceived superficiality aligns with critiques of corporate sustainability frameworks, where

indicators may only ostensibly represent underlying values, potentially leading to consumer skepticism regarding the true strategic intent (Horváth, 2023).

Perceived authenticity and realism: In the domains of generative content and virtual influencers, authenticity serves as a central mediator of credibility. Consumer skepticism is often triggered when a perceived misalignment occurs between AI-generated realism and the brand's established identity, suggesting that authenticity is a fragile prerequisite for trust in synthetic media.

Another variable is anthropomorphism and social presence. The integration of human-like design cues (e.g., conversational language or avatars) facilitates the mitigation of psychological distance. These features enhance affective trust by fostering social presence; however, their effectiveness remains contingent upon the AI agent's underlying functional competence and reliability.

Under the concept of cultural and contextual contingencies, preliminary evidence indicates that trust pathways are socially constructed and vary across cultural orientations. Specifically, the distinction between collectivist and individualist contexts introduces divergent trust formation mechanisms. In collectivist settings, consumers tend to prioritize affective and relational trust, demonstrating greater receptivity to AI agents, particularly AI influencers, that emphasize social presence, community cohesion, and relational embeddedness. In such contexts, AI disclosure may be interpreted through the lens of maintaining social harmony rather than purely as an ethical transparency signal.

Conversely, in individualist contexts, consumers are more likely to prioritize competence-based trust, where credibility is evaluated through performance-related indicators such as accuracy, efficiency, and functional reliability. Here, transparency and data privacy assume a more central role as markers of integrity, and trust is more strongly tied to the perceived effectiveness of the AI system rather than its relational qualities. These distinctions highlight the importance of cultural context as a moderating condition that shapes how trust cues are interpreted and emphasize the need for further cross-cultural validation of AI-mediated trust formation processes.

Ultimately, the findings suggest that trust in AI-mediated brand communication emerges from a complex interaction between technological design, strategic communicative framing, and the consumer's subjective interpretation of these cues.

4.3 RQ3: Evidence for long-term brand loyalty

Evidence regarding long-term loyalty formation remains limited. Most existing studies focus on short-term attitudinal outcomes such as credibility, engagement, or purchase intention, while longitudinal designs are rare. As a result, loyalty is often inferred indirectly through proxy indicators rather than being explicitly measured.

These proxy measures typically include repeat engagement intentions, defined as the consumer's willingness to continue interacting with an AI service or following an AI influencer; positive electronic word-of-mouth (e-WOM), reflecting the likelihood of recommending the AI-mediated brand experience; and brand attachment, referring to the emotional bond developed through parasocial interactions with AI agents, which may serve as a precursor to long-term commitment.

Although increased engagement is consistently observed across studies, durable brand commitment in AI-mediated environments remains empirically underexplored. This gap highlights both a theoretical and methodological limitation in the current literature.

This represents a critical theoretical and methodological gap in the literature. Collectively, these findings support the proposition that AI does not inherently enhance or erode trust. Rather, trust in AI-mediated brand communication emerges as a contingent outcome of technological design, communicative transparency, and consumer interpretation.

To synthesize the fragmented findings across the three primary streams of AI communication, a Conditional Trust Formation Framework is proposed (see Figure 1). This model illustrates that trust is not a direct output of technological deployment but is mediated by specific moderators: Transparency, Anthropomorphism, Perceived Authenticity, and Cultural Context. While different AI types prioritize different pathways (e.g., Chatbots toward Competence-Based Trust versus AI Influencers toward Affective Trust), the framework suggests that these pathways

must converge to foster Long-Term Consumer Loyalty, which remains a critical gap in current longitudinal research.

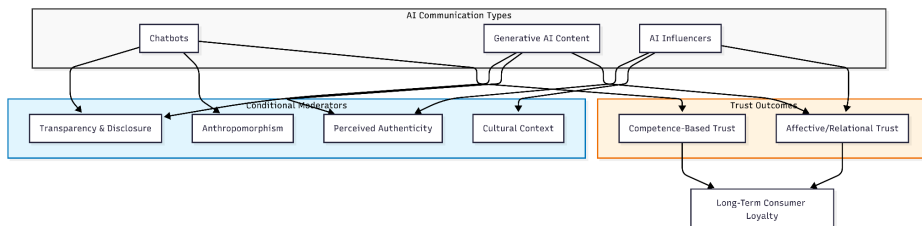


Figure 1: A Conditional Framework of AI-Based Trust Formation in Brand Communication
Source: authors' own edit

4.4 Managerial Implications

The findings of this review offer strategic guidance for brand managers navigating the integration of AI into their communication mix. To manage the "transparency dilemma" effectively, managers should adopt a context-dependent approach to AI disclosure.

When to disclose (High Transparency Strategy): Functional Service Interactions: For chatbots and AI customer service agents, explicit disclosure is recommended. Since trust here is competence-based, consumers value the honesty of the brand and the efficiency of the tool more than human-like "soul".

Considering ethical compliance, disclosure should be a default in markets with high AI literacy or strict ESG governance frameworks to signal brand integrity.

In other cases it is recommended to exercise caution with disclosure, especially in the authenticity-first strategy. For generative AI marketing copy or social media posts aimed at building emotional bonds, managers should be aware that disclosure can trigger the Persuasion Knowledge Model, leading to a drop in perceived authenticity. In influencer marketing, if the goal is to build affective trust through parasocial relationships, the brand must ensure the AI's persona is deeply aligned with the brand's "human" values before disclosing, as transparency can inadvertently highlight a lack of experiential depth.

Managers are encouraged to use anthropomorphic cues (e.g., conversational language or friendly avatars) to mitigate the psychological distance that AI disclosure creates. By balancing transparency with high-quality, realistic design, brands can fulfill ethical obligations without sacrificing consumer engagement.

5 Conclusion and Limitations

This systematic literature review synthesizes 165 peer-reviewed studies to examine how AI-driven brand communication shapes consumer trust and loyalty-related constructs.

In addressing the research questions posed at the outset of this study, the synthesis of 165 articles provides a clear, tripartite resolution. Regarding RQ1, the findings demonstrate that trust is multidimensional and chatbots primarily foster competence-based trust through functional performance, while AI influencers and generative content rely more heavily on affective and authenticity-based pathways. In response to RQ2, the proposed framework identifies that trust outcomes are not absolute but are critically moderated by transparency strategies, anthropomorphic design, and cultural orientation, which can either mitigate or exacerbate consumer skepticism. Finally, concerning RQ3, the review confirms a significant gap in the literature regarding long-term brand loyalty, as the majority of current evidence remains limited to short-term, experimental attitudinal changes. By aligning these findings, this study moves beyond a descriptive summary to offer a structured, theoretical foundation for the next phase of empirical investigation in AI-mediated brand communication.

Despite the growing body of research, several limitations characterize the existing literature.

First, conceptual fragmentation remains significant. Trust, authenticity, credibility, and engagement are often used interchangeably, limiting theoretical precision. Second, the majority of studies focus on short-term attitudinal outcomes, with limited examination of long-term loyalty formation. Third, cross-cultural comparative studies remain scarce, despite evidence that cultural orientation moderates AI trust effects. Finally, generative AI disclosure strategies are under-

theorized, particularly regarding how transparency can be strategically framed without undermining authenticity.

These gaps highlight important directions for future research. Building on the identified fragmentation, an aim could be to develop and empirically test a conditional trust formation framework that integrates AI type, disclosure strategy, perceived authenticity, and consumer AI literacy as interacting determinants of long-term brand loyalty. Particular attention shall be given to longitudinal and cross-cultural validation, addressing the current dominance of short-term experimental designs.

By advancing a theoretically integrated and empirically testable model, future research could seek to move beyond descriptive synthesis toward explanatory theory-building in AI-mediated consumer–brand relationships.

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NAVIGATING THE GREY ZONE: SUSTAINABLE AI GOVERNANCE AND LEADERSHIP IN SMEs

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Small and Medium-sized Enterprises (SMEs) operating within the European Digital Single Market face competing structural pressures: rapid Generative AI adoption driven by market competition, and mounting regulatory obligations under the EU AI Act. This paper addresses the resulting 'compliance vs. competitiveness dilemma' through an integrative literature review that synthesizes the Technology-Organization-Environment (TOE) framework with the business ethics literature on 'AI-washing' - the deliberate or structurally induced misrepresentation of governance practices in regulated deployment contexts. The analysis shows that internal resource constraints - deficits in human capital, financial capacity, and in-house expertise - systematically force SMEs into a 'grey zone' of symbolic compliance, even in the absence of deliberate deceptive intent (Schwaeke et al., 2024). The paper's central contribution is the SME-RAIL (SME Responsible AI Leadership) framework: a three-tier governance model that translates Algorithmic Accountability principles into a phased, resource-proportionate structure for smaller enterprises. The core argument is that the path out of the grey zone requires not additional compliance tools, but a fundamental shift from passive technological adoption to human-centric AI stewardship.

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1 Introduction

The integration of artificial intelligence into SME operations has shifted from a strategic option to a structural imperative - driven by competitive market dynamics that increasingly treat AI-enabled capabilities as baseline requirements rather than differentiators. Yet this same integration exposes SMEs to a mounting regulatory burden, most notably under the EU AI Act, creating a tension between the pressure to adopt and the obligation to govern. This paper examines that tension, which it terms the 'compliance vs. competitiveness dilemma'.

The dilemma is particularly acute within the European Digital Single Market. This integrated economic space is shaped by two opposing forces simultaneously: competitive pressure toward rapid AI deployment on one side, and a uniquely stringent, harmonized regulatory ecosystem on the other. The EU AI Act represents the latest and most consequential pillar of that ecosystem. The result is a landscape in which market imperatives and transparency obligations are not merely in tension but are structurally incompatible for resource-constrained enterprises.

The adoption pressure is well-documented. Generative AI has significantly lowered the access threshold for advanced capabilities, allowing SMEs to deploy tools previously available only to large enterprises (Schwaeke et al., 2024; Rajaram & Tinguely, 2024). At the same time, SME business models typically depend on relational proximity and trust - qualities that third-party 'black box' AI solutions can quietly undermine (Rajaram & Tinguely, 2024). This creates a secondary vulnerability that compounds the governance challenge.

On the regulatory side, the EU AI Act demands strict transparency and human oversight, with specific obligations falling not only on AI system providers but also on deployers - the category that covers most SMEs using third-party solutions (European Commission, 2024). Article 13 requires that users of high-risk AI systems receive clear information about system capabilities; Article 52 mandates explicit disclosure when AI is used to generate or manipulate content. Compliance with these provisions requires documentation, auditing capacity, and dedicated legal knowledge that few SMEs currently possess (Schwaeke et al., 2024; Stampernas & Lambrinoudakis, 2025). Moreover, if an SME customizes a foundation model, it may

itself qualify as a provider, triggering the full set of developer obligations - a dual exposure that makes the compliance challenge uniquely severe.

The gap between these two imperatives frequently pushes SMEs toward a 'grey zone' of symbolic compliance: the adoption of visible governance measures without the organizational substance to back them up. Understanding how this dynamic operates, and how it can be reversed, is the central aim of this study.

Three research questions guide the analysis:

- RQ1: How do external environmental factors (TOE: Environment & Regulation) force SMEs into deceptive governance practices (AI-washing)?
- RQ2: What organizational constraints prevent SMEs from meeting transparency obligations under the EU AI Act?
- RQ3: How can the 'Responsible AI Leadership' model support the establishment of sustainable AI governance in SMEs?

2 Theoretical Background

Synthesizing the Technology-Organization-Environment (TOE) framework with the concept of 'ethics washing' reveals how external environmental factors force SMEs into deceptive practices (RQ1).

2.1 TOE Framework for SME AI Adoption

The Technology-Organization-Environment (TOE) framework provides a theoretical lens for analyzing organizational technology adoption, identifying three contextual dimensions: technological characteristics, organizational readiness, and environmental pressures (Oliveira & Martins, 2011). This model has proven particularly valuable in SME contexts, where resource constraints and external market forces heavily influence digital innovation decisions (Gangwar et al., 2015; Sánchez et al., 2025).

On the technological dimension, artificial intelligence cannot be treated as a traditional, static software product. Rather, it represents a 'Dynamic Capability' that demands continuous strategic governance - not merely one-time acquisition (Mikalef & Gupta, 2021). This distinction matters for SMEs precisely because it shifts the governance burden from a discrete procurement decision to an ongoing organizational commitment.

The environmental dimension amplifies this burden. External market pressure and the 'democratization' strategies of competitors (Shore et al., 2024) push companies toward rapid AI implementation, often before adequate governance structures are in place. At the same time, the regulatory environment - most notably the EU AI Act - transforms AI adoption from a strategic choice into a compliance imperative, imposing transparency and oversight obligations that carry significant resource costs for smaller firms.

The organizational dimension mediates between these two pressures. SMEs' internal capacity constraints - limited human capital, restricted financial resources, and an absence of dedicated legal or technical expertise - determine whether the tension between competitive and regulatory demands can be absorbed or whether it defaults into symbolic compliance. This organizational vulnerability is examined in detail in Section 4.2.

Together, these three dimensions reveal how SMEs face two structurally opposing environmental forces: competitive pressure toward rapid adoption on one side, regulatory stringency on the other. This duality forms the theoretical basis for the 'compliance vs. competitiveness dilemma' this paper addresses.

2.2 From Greenwashing to AI-Washing

The inability to resolve this dilemma frequently forces organizations into the 'grey zone': a state of intentional ambiguity in which superficial compliance mechanisms - such as AI ethics policies without enforcement - substitute for substantive governance reform. In practice, organizations may publicly adopt codes of ethics while, through 'decoupling,' leaving actual operations unchanged. Such symbolic policy implementation is not necessarily driven by malicious intent; it frequently

manifests as a dysfunctional organizational response to genuine resource constraints and the absence of in-house expertise (Stahl et al., 2022; Eccles et al., 2014).

The theoretical foundation of this pattern lies in the ethics washing literature (Bietti, 2020). The literature employs several overlapping but technically distinct concepts in this space - 'ethics washing' (Bietti, 2020), 'machinewashing' (Seele & Schultz, 2022), 'digital ethicswashing' (Schultz et al., 2024), and 'AI-washing' - and these are not fully interchangeable. This paper adopts 'AI-washing' as its primary term, as it most precisely captures the phenomenon under examination: the deliberate or structurally induced misrepresentation of governance practices by organizations deploying these tools in a regulated context. A parallel strand of the literature conceptualizes AI-washing more narrowly, as the misrepresentation or concealment of AI use in consumer-facing communications - an interpretation reflected in regulatory enforcement actions (U.S. SEC, 2024) and consumer trust research (Kirk & Givi, 2025). This paper adopts the broader governance definition, focusing on the organizational conditions that produce deceptive signaling rather than the signals themselves. 'Ethics washing' is retained in the broader theoretical sense established by Bietti (2020) when referring to the general organizational pattern of symbolic compliance; 'machinewashing' and 'digital ethicswashing' are referenced where cited sources use those terms specifically. 'Ethics bashing,' also introduced by Bietti (2020), denotes a distinct phenomenon - the delegitimization of ethics discourse itself - and is not treated as synonymous with any of the above.

Wagner (2019) identifies the key bridge between these concepts: voluntary ethics mechanisms can be deployed strategically to forestall harder legal obligations - functioning as 'ethics as an escape from regulation.' This instrumental use of ethics structures is corroborated by Biddle et al. (2025), who demonstrate how ethics offices can remain purely performative, underscoring the need to distinguish symbolic structures from genuinely empowered ones. The broader organizational pattern - companies shifting between substantive governance and symbolic engagement in response to external scrutiny - is documented by Buhmann et al. (2020) in the context of algorithmic accountability.

Drawing on greenwashing theory, Seele and Schultz (2022) define 'machinewashing' as projecting an appearance of ethical conduct around automated systems without substantive governance to support the claim. This paper treats AI-washing as the

operationally specific form of this phenomenon within regulated deployment contexts, where the gap between declared and actual governance practices carries direct legal consequences under the EU AI Act. The mechanisms are structurally parallel to those described in greenwashing research: selective disclosure and empty policies serve the same signalling function as their environmental counterparts (Lyon & Montgomery, 2015; Schultz et al., 2024).

The legal stakes are substantial. Under the EU's Unfair Commercial Practices Directive (Directive 2005/29/EC), AI-washing falls within the category of unfair commercial practices - making it not merely an ethical failure but a corporate governance liability (Schultz & Seele, 2022). Since the social and environmental impacts of AI should be evaluated and disclosed within the ESG framework, poor disclosure practices and the absence of unified standards enable this misrepresentation to persist at scale (Sætra, 2021; Bozsik et al., 2025). The broader EU push toward transparent, comparable governance metrics - visible in composite indicator frameworks developed for circular-economy performance measurement across Member States - underscores that the standardization challenge extends well beyond AI alone (Kozma et al., 2022).

3 Methodology

The methodological foundation of this study is an Integrative Literature Review (ILR). Although empirical data collection remains dominant in management and organizational sciences, literature synthesis has developed into an independent research methodology in its own right - one capable of generating theoretical models rather than merely cataloguing existing findings (Snyder, 2019). Tranfield et al. (2003) argue that systematic review can produce 'evidence-informed' management knowledge with direct relevance to practitioners, a quality particularly valuable when the empirical record is still thin. This is the case here: although the EU AI Act entered into force in 2024, SMEs' practical experience of operating under its requirements is still accumulating, and longitudinal analysis of governance responses is not yet feasible. Conceptual synthesis is therefore the most appropriate methodological choice at this stage.

The ILR was selected on the basis of Grant and Booth's (2009) review taxonomy. Unlike the classic systematic literature review - which has already mapped the field of digital ethicswashing (Schultz et al., 2024) - the ILR is specifically designed to bridge previously isolated theoretical frameworks (Snyder, 2019; Grant & Booth, 2009). Here, the conceptual bridge connects the technology adoption literature, represented by the TOE framework, with the business ethics scholarship on AI-washing and symbolic compliance. Rather than summarizing past findings, integrative review actively generates new theoretical models through cross-framework synthesis (Torraco, 2005).

To ensure methodological rigor and transparency, the research followed Torraco's (2005) five-phase procedure: (1) problem formulation, (2) data collection, (3) evaluation of sources, (4) analysis, and (5) presentation of results.

The literature search was conducted across three databases - Scopus, Web of Science and Google Scholar - using the following keyword combinations: 'AI governance SME', 'ethics washing artificial intelligence', 'EU AI Act compliance', 'TOE framework AI adoption', and 'algorithmic accountability'. The search was limited to publications between 2019 and 2025, reflecting the period in which generative tools entered mainstream organizational use and the EU regulatory framework took shape. In the preparatory phase of the conceptual scoping process, the Consensus AI-powered literature discovery tool was also employed to identify relevant research directions; sources flagged through this tool were subsequently verified and evaluated manually against the databases listed above.

An initial pool of 148 sources was identified, of which 38 were retained following a two-stage screening process: first by title and abstract relevance, then by full-text evaluation against the governance and organizational focus criteria outlined below. To ground the theoretical background, 10 foundational papers published before 2019 were added, yielding a final corpus of 48 references. Sources were excluded if they treated AI-washing exclusively as an external communication or marketing phenomenon, or if they focused on large enterprises without reference to resource-constrained contexts.

This boundary requires explicit justification. The concept of AI-washing as defined by Seele and Schultz (2022) and Schultz et al. (2024) inherently encompasses an external communication dimension - misleading signals directed at stakeholders are, by definition, outward-facing. The research questions of this study, however, concern the internal governance failures that produce those signals, not the signals themselves. Sources focused exclusively on AI-washing as a marketing or public relations problem - without examining the organizational conditions that generate it - were therefore excluded as outside the structural diagnosis this paper advances. The external stakeholder communication dimension is recognized as a complementary research direction and is identified as a priority for future empirical work.

The synthesized results follow a conceptual rather than chronological structure (Torraco, 2016): from compliance pressure (TOE) through the governance failures that produce AI-washing, to the Responsible AI Leadership model proposed as a structural response. Each retained source was coded along three dimensions: (1) the type of compliance pressure described (regulatory, competitive, or reputational); (2) the organizational response pattern identified (substantive governance, symbolic compliance, or grey zone behavior); and (3) the proposed mitigation mechanism, if any. This coding structure enabled the cross-source identification of the TOE-AI-washing linkage and the organizational conditions that sustain it, which form the analytical backbone of Sections 4.1 and 4.2.

4 Results

The analysis below traces how the three TOE dimensions - environmental, technological, and organizational - generate the governance failures that produce AI-washing in SME contexts.

4.1 Environmental Drivers of Deception

For SMEs, the environmental and technological pillars of the TOE framework currently generate overlapping pressures that push organizations toward the 'grey zone' of symbolic compliance. On one hand, the perceived usefulness of AI (Davis, 1989) and the imperative to survive in a turbulent market (Shore et al., 2024) drive companies toward immediate, often hasty adoption. This pressure is particularly

pronounced in sustainability-sensitive sectors, where AI-based tools are actively promoted as instruments for fostering energy awareness and behavioral change - adding a reputational dimension to the adoption imperative (Fűrész, 2025). On the other hand, the EU AI Act's risk-based model imposes compliance obligations that present disproportionate challenges for smaller firms even at a conceptual level (Mancheva, 2022), compounded by the multi-level governance structure that generates opaque institutional pressure on SMEs (Cancela-Outeda, 2024).

As detailed in Section 2, Articles 13 and 52 impose specific disclosure obligations that transform AI from a competitive asset into a compliance burden. Interpreting these provisions, classifying systems by risk level (Annex III), conducting third-party audits (Articles 43-44), and producing technical documentation (Article 11) represent precisely the 'disproportionate compliance costs' identified by Schwaeye et al. (2024). These requirements are embedded within the EU's seven-point 'Trustworthy AI' framework, which links abstract ethical principles to mandatory regulatory obligations (Díaz-Rodríguez et al., 2023).

This is where the environmental pillar of the TOE model intersects directly with the AI-washing pattern defined in Section 2.2. SMEs already dependent on unverifiable 'black box' solutions due to vendor lock-in (Mikalef & Gupta, 2021) lack the internal capacity to meet these expectations. The combination of external competitive pressure and regulatory stringency - pulling in opposite directions simultaneously - is what makes symbolic compliance the path of least resistance. Rather than investing in substantive governance, SMEs follow Wagner's (2019) logic of 'ethics as an escape from regulation': superficial measures substitute for structural reform, and the organization slides into AI-washing not necessarily through deliberate deception, but through the accumulated weight of an unresolvable dilemma.

Figure 1 illustrates this structural pathway - from the three TOE dimensions through the compliance dilemma to the grey zone and its AI-washing outcome.

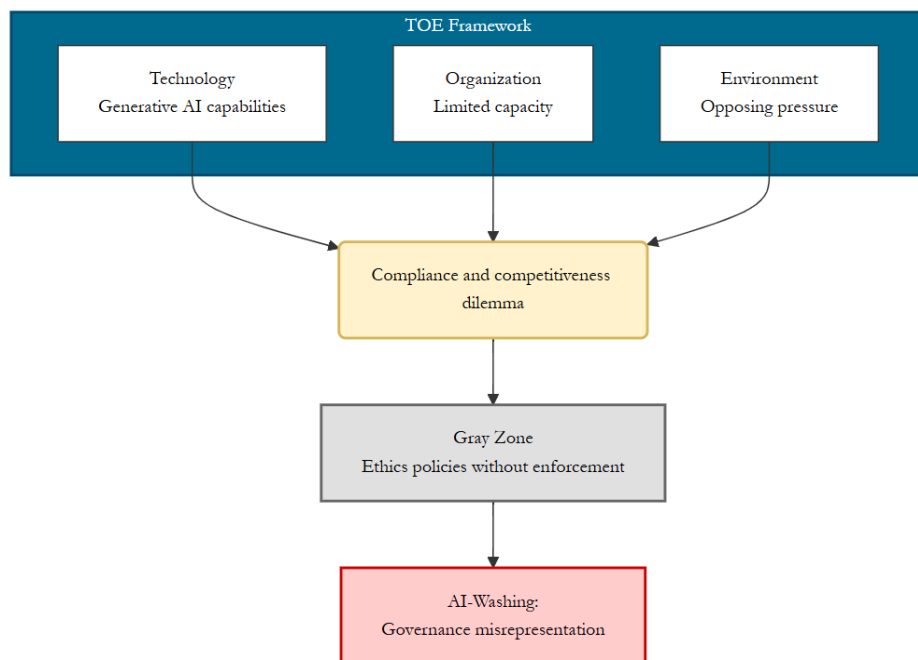


Figure 1: TOE framework dimensions and the structural pathway to AI-washing in SMEs

Source: Authors' own elaboration.

4.2 Organizational Constraints (RQ2)

The retreat into symbolic compliance that external pressures initiate is made structural by what the organizational pillar of the TOE framework reveals: SMEs lack the internal capacity to implement genuine AI governance. Stahl et al. (2022) document that resource-constrained enterprises face a significant human capital deficit - lacking both the technical expertise required for algorithmic auditing and the dedicated legal knowledge needed to navigate the EU AI Act. This knowledge gap is compounded by the financial constraints that prevent even the acquisition of external transparency tools.

Digitalization more broadly exposes interfunctional coordination problems within SMEs (Ruiz-Alba et al., 2020), and AI adoption amplifies these into gaps in technological readiness and core business function integration (Le Dinh et al., 2025). The regulatory stakes make this organizational unpreparedness particularly consequential: SME awareness of the EU AI Act remains limited despite years of

GDPR compliance struggles (Joswig & Kurz, 2025), while the Act prescribes financial sanctions calculated as a percentage of annual turnover - a penalty structure whose full weight most affected organizations have not yet confronted (Stampernas & Lambrinoudakis, 2025). The same competence and resource gaps that generate symbolic compliance also prevent SMEs from realizing AI's documented potential for managerial productivity and decision-making efficiency - a double cost that the governance literature has only recently begun to quantify (Garg et al., 2024).

Facing this combination of pressures, SMEs resort to the washing mechanisms identified in Section 2 (Lyon & Montgomery, 2015; Bietti, 2020). They substitute substantive transparency with nominally ambitious but unenforceable ethics policies, and shift accountability to third-party vendors through selective disclosure - a pattern Biddle et al. (2025) identify as characteristic of organizations that have ethics structures in form but not in function. These deficiencies are self-reinforcing: the less internal capacity an SME has, the more it relies on symbolic measures, and the further it retreats from the governance substance the EU AI Act requires. Breaking this cycle is the challenge the SME-RAIL framework addresses in Section 4.3.

4.3 The SME-RAIL Framework

The SME-RAIL framework translates the governance failures identified in Sections 4.1 and 4.2 into a structured operational response. The three tiers are designed to be implemented sequentially: the Strategic Level establishes the accountability foundation without which the Operational and Market levels cannot function. Each tier addresses a distinct failure mode - the absence of personal accountability, the absence of documented practice, and the absence of external trust - and together they form a minimum-viable governance structure calibrated to the resource constraints the analysis diagnoses.

The framework aligns internal organizational capabilities across the strategic and operational levels with the external stakeholder expectations that define the market dimension, as set out in Table 1.

Table 1: The SME-RAIL (Responsible AI Leadership) Governance Framework

Governance Dimension	Conceptual Foundation	Operational Mechanism	Desired Outcome
1. Strategic Level (Top Management Team)	Complex Leadership & Human-centric stewardship (Floridi, 2023; Peñarroya-Farell et al., 2025)	Designating a senior manager as 'AI Steward' with personal accountability for disclosure obligations under Articles 13 and 52 of the EU AI Act; treating human oversight as a structural governance commitment rather than a technical fallback.	Overcoming the 'Compliance vs. Competitiveness' dilemma.
2. Operational Level (Accountability)	FAT Framework & Algorithmic accountability (Shin & Park, 2019; Papagiannidis et al., 2025)	Maintaining an internal 'AI register' documenting every third-party system in use, the data it accesses, and its decision scope; applying human-in-the-loop validation to high-impact outputs such as automated pricing or predictive marketing.	Eliminating symbolic compliance (AI-washing).
3. Market Level (Stakeholder Trust)	Entrepreneurial Resilience & B2B Market Knowledge (Shore et al., 2024; Paschen et al., 2019)	Proactively communicating governance practices - including the scope of the AI register and the validation process - to B2B partners as part of standard contractual interactions; using transparency as a differentiating signal rather than a compliance obligation.	Long-term market resilience and deep B2B trust.

Source: Authors' own elaboration based on the literature synthesis.

5 Discussion: Responsible AI Leadership

The following sections address RQ3 by tracing how the SME-RAIL framework translates into leadership practice - from philosophical grounding through operational accountability to market-level trust.

5.1 Paradigm Shift: From Philosophical Foundations to Complex Leadership

The human-in-the-loop principle that underpins the SME-RAIL framework is not merely a technical safeguard - it reflects a philosophical reality about the nature of current AI systems. As Floridi (2023) argues, these models function as agents without genuine intelligence or intention: they produce outputs without understanding, purpose, or moral standing. Because the technology cannot bear responsibility, the full weight of accountability rests on the human decision-makers who deploy and oversee it. This concentration of responsibility in human hands is what makes governance a leadership question rather than an IT question. The three-tier structure of the SME-RAIL framework is a direct organizational response to this reality - not because AI is inherently dangerous, but because its consequences are, and no internal mechanism will self-correct for absent oversight or poor judgment.

Organizations must therefore move beyond technology acquisition and embed governance accountability as a core leadership responsibility. This is a significant change management challenge: corporate leadership often experiences tension between short-term performance pressures and longer-term legal and ethical expectations (Hickman & Petrin, 2020), and AI governance adds a new layer of complexity to that tension. Complex Leadership theory offers a productive framework for navigating it, treating governance not as a constraint imposed on strategy but as a dimension of leadership capability in itself (Peñarroya-Farell et al., 2025).

The concept of Responsible AI Leadership builds on this foundation. Drawing on Stahl and Eke's (2024) ethical grounding and the EU's 'Trustworthy AI' requirements (Díaz-Rodríguez et al., 2023), it represents a governance shift from technology-centric adoption to human-centric stewardship - one that prioritizes algorithmic accountability over efficiency-focused transformation. Within the SME context, this means converting the human-in-the-loop principle from a baseline compliance mechanism into a continuous organizational commitment: transparency becomes a relational asset, and governance becomes the foundation of long-term stakeholder trust.

5.2 Mitigating "Washing": Algorithmic Accountability in Practice

AI-washing exploits the information asymmetries between an organization and its stakeholders. Kemper and Kolkman (2019) establish that algorithmic accountability requires an audience capable of scrutinizing governance claims - symbolic ethics structures generate no genuine trust precisely because they cannot withstand that scrutiny (Buhmann et al., 2020).

The SME-RAIL framework addresses this through the FAT (Fairness, Accountability, Transparency) principles (Shin & Park, 2019), translating them into three concrete governance steps accessible to resource-constrained enterprises. Rather than deploying costly compliance software, an SME can begin by maintaining a simple internal 'AI register' that maps where third-party algorithms operate and what data they access. This documented transparency must be coupled with human-in-the-loop validation: a designated employee reviews high-impact outputs - automated pricing decisions, predictive B2B marketing messages - before they reach partners or customers. Personal accountability is then anchored by designating an existing senior manager as 'AI Steward,' responsible for the organization's disclosure obligations under Articles 13 and 52 of the EU AI Act.

A legitimate objection concerns the framework's own resource demands. Appointing an AI Steward, maintaining a register, and running validation protocols all require time and organizational capacity - the very resources identified as scarce in Section 4.2. This tension is real but resolvable through a straightforward cost-risk comparison. The EU AI Act's financial penalties are calculated as a percentage of annual turnover (Stampernas & Lambrinoudakis, 2025), meaning that for most SMEs, a single enforcement action would far exceed the cumulative cost of these governance steps. The SME-RAIL framework is not designed as a full compliance infrastructure to be deployed at once, but as a phased, minimum-viable structure in which each step generates immediate risk reduction. Designating an existing manager as AI Steward, for instance, requires no new hire - it requires a redefinition of accountability.

5.3 Business Value: Entrepreneurial Resilience and B2B Trust

Responsible AI Leadership carries strategic value beyond regulatory compliance. A significant proportion of SMEs operate within supply chains and business networks where AI-generated insights - customer demand forecasting, predictive pricing, automated partner communications - are becoming standard commercial tools. In these B2B contexts, transparent AI disclosure is not optional; it is a precondition for maintaining the relational trust on which SME business models depend (Paschen et al., 2019).

When organizations communicate their AI governance practices proactively - framing data security and algorithmic transparency as standard elements of commercial relationships rather than legal obligations (Eid et al., 2024) - governance becomes a market signal. Over time, this conscious integration builds the adaptive capacity that Shore et al. (2024) identify as the foundation of entrepreneurial resilience during periods of market turbulence. The organizations that establish governance credibility before it is demanded are better positioned to maintain partner trust when regulatory scrutiny intensifies - a scenario the EU AI Act's phased implementation schedule makes increasingly likely.

6 Conclusions

This paper has examined how SMEs operating within the European Digital Single Market navigate the structural tension between competitive pressure toward rapid AI adoption and the transparency obligations imposed by the EU AI Act. The integrative literature review demonstrates that this tension is not resolvable through compliance tools alone: the internal resource constraints documented across the organizational pillar of the TOE framework - deficits in human capital, financial capacity, and legal expertise - systematically generate symbolic compliance regardless of organizational intent.

The analysis responds to all three research questions: it identifies the environmental and organizational forces that push SMEs into the grey zone (RQ1, RQ2), and proposes a concrete, resource-proportionate governance model as a structured response (RQ3).

The SME-RAIL framework operationalizes this response through FAT principles into three sequential governance tiers – strategic accountability, operational documentation, and market-facing transparency – providing a minimum-viable governance structure calibrated to the constraints it diagnoses. The framework's central argument is that transparency, reframed as a relational asset rather than a regulatory burden, creates the conditions for long-term B2B trust and entrepreneurial resilience.

The framework's applicability is not uniform across the EU. SMEs operating in member states with stronger administrative support infrastructure - such as dedicated AI regulatory sandboxes or national SME compliance programs - face a materially different implementation environment than those in regions where such mechanisms are absent. Similarly, sectors subject to high-risk AI classification under the Act face more immediate governance obligations than those operating outside that scope. Future empirical work should account for these regional and sectoral variations when testing the framework's practical feasibility.

6.1 Managerial and Policy Implications

For SME leadership, the practical implication is direct: AI adoption cannot be managed as a standard IT procurement decision. Because the technology produces consequential outputs without any capacity for self-correction or judgment, its integration places the full weight of governance responsibility on the organization's leadership. The SME-RAIL framework operationalizes this responsibility through three concrete steps - designating an AI Steward, maintaining an AI register, and instituting human-in-the-loop validation - each of which generates measurable risk reduction without requiring new organizational infrastructure.

For policymakers and regulatory authorities, the findings highlight a structural problem with enforcement-only approaches. Financial penalties calculated as a percentage of turnover create significant deterrence on paper, but without dedicated support mechanisms - SME-specific regulatory sandboxes, accessible open-source compliance tools, and clear operational guidelines - they are more likely to drive smaller enterprises deeper into the grey zone than to produce genuine transparency. Achieving substantive compliance in the digital single market requires actively reducing the cost of governance, not only raising the cost of non-compliance.

6.2 Limitations and Future Research

The primary limitation of this study is its conceptual nature. The SME-RAIL framework is grounded in a theoretically rigorous literature synthesis, but its practical feasibility has not yet been tested empirically. Future research should employ both quantitative and qualitative methods - including in-depth interviews with SME leaders and case studies in B2B networks - to examine how the framework performs under real organizational conditions, with particular attention to the resource and sectoral variations noted above.

A second limitation concerns scope. By focusing on the internal governance failures that produce AI-washing, the study deliberately sets aside the external communication dimension of the phenomenon - the misleading signals directed at stakeholders. This dimension is recognized as a complementary research priority, and its empirical investigation would extend the analytical framework developed here.

Declaration of AI usage: During the preparation of this work, the authors used Consensus AI for literature search and conceptual discovery, and Claude AI and Gemini for structural refinement and language editing. After using these tools, the authors thoroughly reviewed and edited the content as needed, and take full responsibility for the final content of the publication.

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DOES INSTITUTIONAL QUALITY SHAPE THE LAFFER CURVE? EVIDENCE FROM SELECTED EU ECONOMIES

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This paper examines whether institutional quality shapes the relationship between capital taxation and public revenues within the Laffer curve framework. Using tax revenues as a percentage of GDP as the dependent variable, and the Effective Average Tax Rate (EATR) on capital, government effectiveness, and rule of law as key determinants, the analysis explores how institutional capacity conditions fiscal performance. The sample comprises nine EU economies: Denmark, the Netherlands, Sweden, Estonia, Portugal, the Czech Republic, Greece, Bulgaria, and Romania, over the period 2004–2023. Employing the Pooled Mean Group (PMG) estimator, the results indicate a positive long-run effect of EATR on revenues and a negative coefficient on its squared term, confirming a non-linear Laffer-type relationship. Institutional indicators are positively and significantly associated with revenues, while the error correction term confirms stable long-run adjustment. Overall, stronger institutions shape the nonlinear revenue response, contributing to greater fiscal sustainability.

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1 Introduction

The relationship between taxation and public revenue has long occupied a central position in fiscal economics. One of the most influential theoretical frameworks explaining this relationship is the Laffer curve, which describes the nonlinear relationship between tax rates and tax revenues. According to this framework, tax revenues initially increase with higher tax rates due to the arithmetic effect (Beljić et al. 2023), but beyond a certain threshold, further increases reduce revenues as behavioral responses shrink the tax base. While the theoretical intuition of the Laffer curve is well established (Blinder, 1981; Agell & Persson, 2001; Lin & Jia, 2019), empirical evidence regarding its magnitude, symmetry, and policy relevance remains mixed (Brill & Hassett, 2007; Trabandt & Uhlig, 2011). Most empirical research concentrate primarily on identifying the revenue-maximizing tax rate, typically focusing on marginal income taxation. However, less attention has been devoted to the role of institutional quality in shaping the position and slope of the Laffer curve, particularly in the context of capital taxation. This omission is substantively important. If tax avoidance, compliance behavior, enforcement capacity, and taxpayer trust are shaped by institutional structures, then the revenue effects of capital taxation cannot be fully understood without accounting for institutional quality (Horodnic, 2018).

Recent literature suggests that revenue responses to taxation are strongly influenced by tax morale and administrative capacity rather than solely by real economic adjustments (Saez & Stantcheva, 2018). In institutional environments characterized by weak enforcement and low trust, higher tax rates may primarily stimulate avoidance and evasion rather than productive responses. Conversely, in countries with effective governments and strong rule of law, higher statutory or effective tax rates may not necessarily erode the tax base to the same extent. This perspective implies that institutional quality may shift the peak of the Laffer curve and affect the range within which tax rates increase revenues.

Against this backdrop, this study investigates the long-run relationship between public revenues and capital taxation, emphasizing whether institutional quality shapes the Laffer curve. Using tax revenues as a percentage of GDP as the dependent variable and the Effective Average Tax Rate (EATR) on capital, a measure of the effective corporate tax burden that accounts for statutory tax rates

and relevant tax allowances and reliefs, as the core explanatory variable, alongside government effectiveness and the rule of law, which capture the quality of public administration and the strength of legal and institutional frameworks, the analysis examines how institutional trust conditions the revenue effects of taxation.

The empirical research focuses on nine EU economies: Denmark, the Netherlands, Sweden, Estonia, Portugal, the Czech Republic, Greece, Bulgaria, and Romania, representing heterogeneous levels of institutional trust and administrative capacity. This heterogeneity provides a suitable framework for assessing whether stronger institutions allow countries to maintain higher effective capital tax rates without shifting into the revenue-reducing portion of the Laffer curve. By employing the Pooled Mean Group (PMG) method over the period 2004–2023, this paper contributes to the literature in three main ways. **First**, it provides long-run evidence of a nonlinear relationship between capital taxation and revenue generation, confirming the existence of a Laffer-type effect. **Second**, it explicitly integrates institutional quality into the Laffer framework, moving beyond purely rate-based analyses. **Third**, it offers policy-relevant insights for EU fiscal governance by demonstrating that institutional strength allows countries to maintain effective capital taxation without undermining revenue performance. Rather than treating the Laffer curve as a purely mechanical relationship between tax rates and revenues, this paper conceptualizes it as institutionally conditioned. It redirects the debate from whether the Laffer curve exists to how institutional quality affects its empirical relevance.

Therefore, the hypotheses tested in this paper are:

H1: *The relationship between effective average tax rate and tax revenues is nonlinear, consistent with a Laffer-type mechanism, and this nonlinear effect is more pronounced in economies with higher institutional quality.*

H2: *Institutional quality, measured by government effectiveness and rule of law, significantly shapes the short- and long-run relationship between capital taxation and tax revenues, enhancing revenue performance in higher-quality institutional environments*

The remainder of the paper is structured as follows. Following the Introduction, Section 2 reviews the relevant empirical literature. Section 3 provides a descriptive overview of developments in tax revenues, effective average tax rates, the rule of law, and government effectiveness in the selected EU economies over the observed period. Section 4 outlines the data and methodological framework, while Section 5 presents and discusses the empirical results. The final section concludes and highlights the main implications of the findings.

2 Literature review

A substantial body of empirical research identifies **Effective Average Tax Rates (EATR)** as a more appropriate measure of the effective tax burden than statutory rates, particularly in analyses of tax revenues. By incorporating deductions, allowances, and tax provisions, EATR captures the actual tax base conditions under which capital income is generated (Devereux & Sørensen, 2006; Barrios et al., 2014). As Devereux and Sørensen indicate, reliance on statutory rates alone may distort assessments of fiscal capacity and revenue potential. Empirical evidence confirms that effective taxation measures are systematically linked to economic decisions that directly determine the size of the tax base. Egger et al. (2009) show that investment allocation responds to effective rather than statutory taxation, implying that EATR is more closely aligned with realized tax revenues. Cross-country analyses within the EU further document substantial variation in effective capital taxation, suggesting that revenue performance cannot be evaluated independently of effective tax burdens (Feldstein, Dicks-Mireaux & Poterba, 1983).

A substantial strand of the literature argues that the **Laffer curve** should not be interpreted as a universal structural constant, but rather as a context-dependent relationship between tax rates and revenues. Its empirical shape is shown to reflect underlying economic and institutional conditions that influence how changes in effective taxation translate into adjustments in the tax base. Monissen (1999) argues that the existence and position of a revenue-maximizing rate depend on the institutional environment in which taxation operates (Brill & Hassett, 2007). In weak institutional settings, higher effective tax rates may primarily erode the tax base; in stronger institutional environments, an interior revenue maximum is more likely to emerge (Fernández-Rodríguez, García-Fernández, & Martínez-Arias, 2021). Empirical evidence confirms nonlinear tax–revenue relationships while highlighting

substantial variation in estimated turning points (Akgun, Bartolini, & Cournède, 2017). Hsing (1996) demonstrates that the revenue-maximizing rate is sensitive to structural and policy conditions. Heijman and van Ophem (2005) further show that increases in tax rates may shift activity toward the informal sector, implying that revenue declines may reflect institutional limitations in enforcement rather than purely real economic contraction. Panel evidence from European economies reveals pronounced cross-country heterogeneity in both the slope and the revenue-maximizing point of the tax–revenue relationship (Ferreira-Lopes, Martins & Espanhol, 2020). General equilibrium analyses similarly indicate that the peak of the Laffer curve varies with structural characteristics of the economy (Lin & Jia, 2019). The absence of a common turning point across countries suggests that the nonlinear relationship between effective taxation and revenue is conditioned by country-specific structural and institutional factors.

Recent research increasingly recognizes **institutional quality** as a fundamental determinant of fiscal performance. Empirical evidence indicates that governance dimensions such as regulatory effectiveness, corruption control, and rule of law exert measurable effects on tax revenue performance (Hussain & Ilahi, 2016). Institutional capacity influences compliance behavior, enforcement efficiency, and the credibility of fiscal policy, thereby affecting the elasticity of the tax base (Carbonara et al. 2024). Sojoodi and Alamdari (2026) document a bidirectional relationship between institutional quality and tax revenue, suggesting that institutions not only shape fiscal outcomes but are themselves reinforced by revenue capacity. Cross-country evidence further indicates that the effect of institutional quality, particularly rule of law, varies with the level of economic development (Günel & Didinmez, 2022). This heterogeneity implies that institutional strength may condition the responsiveness of tax revenues to changes in effective taxation. Moreover, Castiglione, Infante, and Smirnova (2015) demonstrate that institutional development and income levels are mutually reinforcing, underscoring the mediating role of governance in shaping macroeconomic performance. Taken together, this body of literature indicates that institutional quality may affect not only the level of tax revenues but also the structural characteristics of the taxation–revenue relationship. Within a Laffer framework, stronger institutions can reduce avoidance and informality, potentially influencing the position or curvature of the revenue-maximizing relationship.

Although effective taxation, nonlinear revenue effects, and institutional quality have been extensively studied, these strands of literature remain largely disconnected. This paper bridges this gap by integrating EATR and its squared term with institutional indicators within a unified nonlinear panel framework to examine whether institutional quality conditions the existence and positioning of the Laffer curve in EU economies.

3 Empirical Setting and Descriptive Evidence

This section provides a graphical and descriptive assessment of the relationship between capital taxation and tax revenues in the selected EU economies over the period 2004–2023. The aim is to explore preliminary patterns in the data, with particular attention to potential nonlinearities consistent with the Laffer framework and cross-country differences in institutional quality. Figure 1 presents a stylized representation of the Laffer curve, illustrating the theoretical nonlinear relationship between tax rates and tax revenues, whereby revenues initially rise with higher taxation but may decline beyond a certain threshold. The inclusion of the squared EATR term in the empirical model directly tests this nonlinearity. Point E denotes the revenue-maximizing tax rate, which should not be confused with the socially optimal rate that minimizes economic distortions. Owing to the theoretical symmetry of the curve, two different tax rates, one relatively low (point A) and one relatively high (point B), may generate identical revenue levels (Brill *ii* Hassett, 2007; Trabandt *ii* Uhlig, 2011).

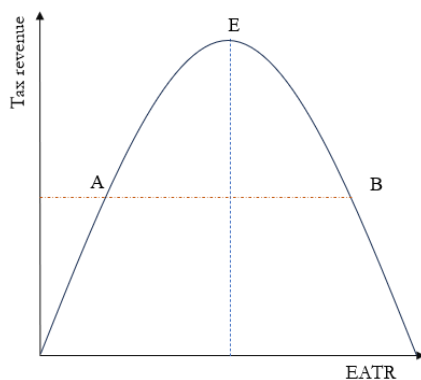


Figure 1: Laffer curve

Source: Authors' presentation based on Laffer (2004).

The evolution of tax revenues over the sample period is presented to provide preliminary descriptive evidence on cross-country dynamics and to assess their consistency with the theoretical predictions of the Laffer framework.

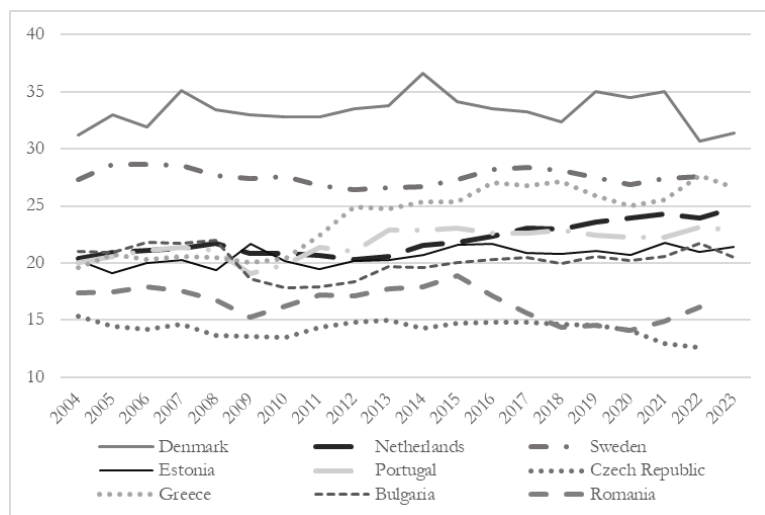


Figure 2: Tax revenue trend in selected EU economies.
Source: Authors' own presentation based on World Bank data.

Empirical evidence for the selected EU economies indicates stable to moderately positive trends in tax revenues over the observed period (Figure 2). Estonia, Sweden, and Portugal exhibit the greatest stability in tax revenues as a percentage of GDP. Denmark recorded a noticeable peak in 2014, reflecting restrictive fiscal measures implemented to support post-crisis recovery following the 2008 financial shock (Glavaški, Beker Pucar & Stojkov, 2022). Greece experienced a substantial increase in tax revenues, from 19.6% to 26.6%, particularly after 2011, which may be associated with fiscal consolidation measures introduced under successive bailout programs (Beljić & Glavaški, 2021). In contrast, the Czech Republic displayed a declining trend, with tax revenues decreasing from 15.3% to 12.6% over the same period. From a Laffer curve perspective, such cross-country heterogeneity suggests that economies may operate at different segments of the tax rate–revenue relationship, where institutional capacity and compliance conditions potentially influence the effectiveness of taxation in generating public revenues.

The following figures present the evolution of EATR and tax revenues (as a percentage of GDP) across the selected EU countries, highlighting cross-country differences and potential nonlinear revenue responses consistent with the Laffer framework. Empirical evidence for the selected EU economies indicates a general downward trend in the EATR over the period 2004–2023 (Figure 3). Economies characterized by higher levels of institutional quality reduced their EATR by approximately 6 percentage points (pp). Portugal, however, exhibited a temporary deviation from this pattern following the Global Financial Crisis of 2008, increasing its EATR from 23.7% to 28.4%. This upward adjustment proved short-lived, as Portugal subsequently aligned with the broader EU trend, reducing its EATR to 21.4%. Among economies with lower institutional quality, Bulgaria and Romania significantly reduced their EATRs shortly after EU accession (2005). Notably, their current EATR levels, 9% and 14.5%, respectively, remain below the OECD/G20 BEPS minimum threshold of 15%. Estonia similarly records an EATR below the proposed minimum, at 10.2%.

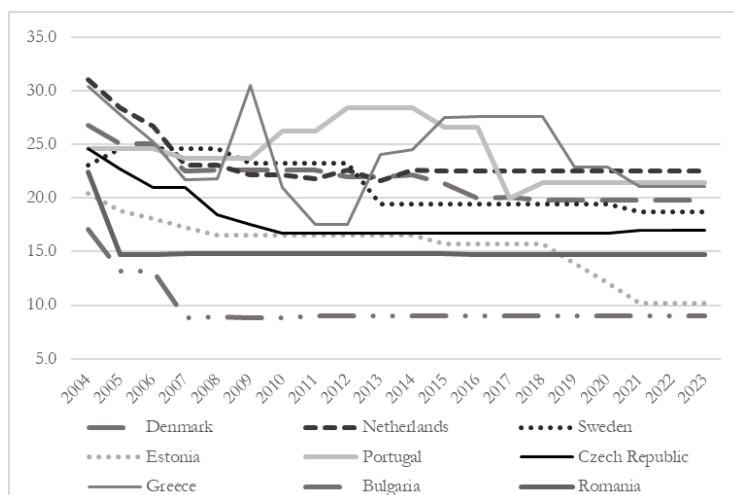


Figure 3: EATR trend in selected EU economies.

Source: Authors' own presentation based on OECD data.

Finally, the evolution of institutional indicators, government effectiveness and rule of law, are presented. The graphical evidence reveals substantial heterogeneity in institutional quality across the selected EU economies. These differences provide an initial indication that revenue performance may not depend solely on tax rates but

also on institutional capacity, which could influence compliance, enforcement, and overall fiscal effectiveness. Empirical evidence (Figure 4a) indicates that Denmark, the Netherlands, and Sweden consistently exhibit the highest levels of rule of law among the selected EU economies, although Sweden has recorded a slight decline since 2018, reaching 93.3. The most pronounced improvements over the observed period were achieved by Estonia and the Czech Republic, whose rule of law indicators increased from 76.9 to 89.6 and from 70.2 to 84.4, respectively, positioning them among the strongest institutional performers. Bulgaria and Romania remain the lowest-ranked countries in this dimension, despite observable improvements over time. In contrast, Greece is the only selected economy that experienced a substantial deterioration in rule of law, with its index declining from 77.4 to 57.7.

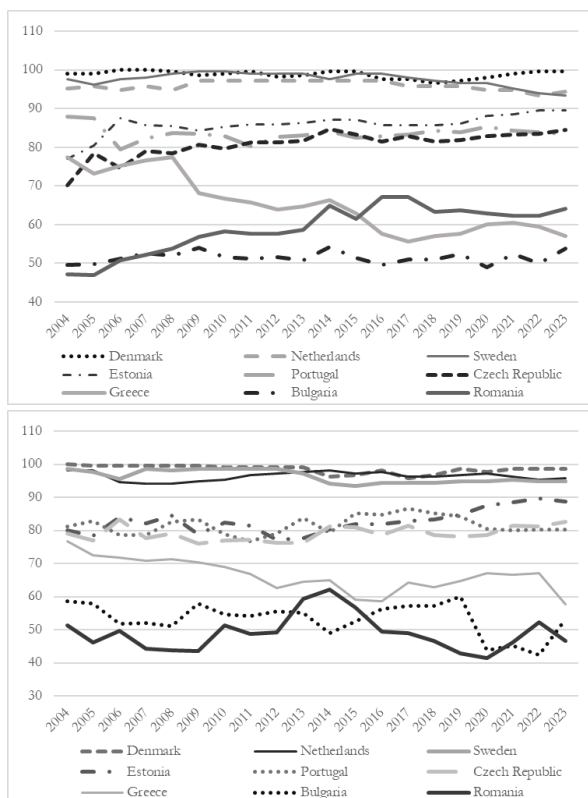


Figure 4: Rules of Law (a) and Government effectiveness (b) trends in selected EU economies.

Source: Authors' own presentation based on World Bank data.

Regarding the government effectiveness index (Figure 4b), Denmark records the highest value (98.6), followed by the Netherlands and Sweden. Portugal also displays a stable performance. Estonia and the Czech Republic demonstrate significant improvements, increasing from 80 to 88 and from 79 to 83, respectively. Conversely, Greece, Bulgaria, and Romania show declines in government effectiveness, with Greece experiencing the most pronounced reduction, from 76.6 to 57.4. Such institutional divergence is particularly relevant in the context of the Laffer framework, as stronger governance capacity may enhance tax administration, compliance, and the overall responsiveness of revenues to changes in tax policy.

4 Methodology and Model Specification

The econometric framework, based on macro panel data, allows for the analysis of both short-run and long-run relationships over time and across the selected EU economies between the dependent variable, tax revenue (as a percentage of GDP), and the key explanatory variables: the Effective Average Tax Rate (EATR), $EATR^2$ (the quadratic specification of EATR which enables an empirical assessment of the Laffer-type nonlinearity), rule of law, and government effectiveness. The dataset constitutes a relatively large macro panel comprising nine EU economies ($N = 9$). The sample is heterogeneous and can be divided into three subgroups: economies with high institutional quality (Denmark, the Netherlands, Sweden), medium institutional quality (Estonia, Portugal, Czech Republic), and low institutional quality (Greece, Bulgaria, Romania). The observation period spans 2004–2023 ($T = 19$). The period was defined based on the 2004 EU enlargement and the availability of consistent EATR data across all selected economies. Accordingly, this study employs estimation techniques suitable for large- T dynamic panels to test the proposed hypotheses (H1–H2), primarily through the comparison of Mean Group (MG) and Pooled Mean Group (PMG) estimators, alongside additional robustness checks using Panel Corrected Standard Error (PCSE).

PMG estimator, introduced by Pesaran, Shin, and Smith (1999), is designed for dynamic panel data models with large time dimensions. It allows short-run parameters, error variances, and adjustment dynamics to vary across cross-sectional units, while imposing homogeneity on the long-run coefficients. This specification is particularly suitable for heterogeneous panels in which economies may differ in short-run behavior but share a common long-run relationship. The Mean Group

(MG) estimator allows full heterogeneity across cross-sectional units, permitting both short-run dynamics and long-run coefficients to differ across panels. The Hausman test could be used to distinguish whether to use the MG or PMG estimator (Hausman, 1978). In the context of EU member states, the PMG framework enables convergence toward a homogenous long-run equilibrium, while permitting differences in the speed of adjustment across countries. As those methods are defined as panel error-correction models, the model could be described as:

$$\Delta y_{it} = \Phi_i(\Phi_i y_{i,t-1} - \theta x_{i,t-1}) + \sum_{j=1}^{p-1} \Lambda_{ij} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \gamma_{ij} \Delta x_{i,t-1} + u_{it} \quad (1)$$

where y_{it} is the dependent variable for economy i and time t ; θ represents the common long-run relationship between observation units, while Φ_i in the form of a model with equilibrium error correction represents the error correction parameter that captures the speed of adjustment towards the long-run equilibrium, Λ_{ij} represents the short-run coefficients of the lagged dependent variable, and γ_{ij} represents the short-run coefficients of the lagged independent variables.

Using the specification described, we estimated the following model:

$$\begin{aligned} \Delta taxrev_{it} = & \Phi_i(\Phi_i taxrev_{i,t-1} - \theta eatr'_{1i,t-1} - \theta eatr2'_{1i,t-1} - \theta law_{2i,t-1} - \\ & \theta goveff_{2i,t-1}) + \sum_{j=1}^{p-1} \Lambda_{ij} \Delta taxrev_{i,t-1} + \sum_{j=0}^{q-1} \gamma_{ij} \Delta eatr'_{1i,t-1} + \\ & \sum_{j=1}^{p-1} \Lambda_{ij} \Delta eatr2'_{1i,t-1} + \sum_{j=0}^{q-1} \gamma_{ij} \Delta law_{2i,t-1} + \sum_{j=0}^{q-1} \gamma_{ij} \Delta goveff_{i,t-1} + u_{it} \end{aligned} \quad (2)$$

where the dependent variable is *taxrev* which represents the tax revenue as percentage of GDP, in 9 EU economies (source: World Bank database), while the model also includes four independent variables: *eatr* shows the effective average tax rates for each EU economies, based on the Devereux/Griffith methodology available in the paper by Spengel et al. (2020) and OECD data base. This provided accurate data on the effective average tax rates, which we identified to be more reliable for our analysis than corporative tax rates ($\beta_1 > 0$). *eatr2* is quadratic specification which is introduced to test for nonlinear revenue effects and to examine whether the tax–revenue relationship exhibits a Laffer-type functional form ($\beta_2 < 0$). *law* represents rule of law index which captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as

well as the likelihood of crime and violence. Percentile rank indicates the country's rank among all countries covered by the aggregate indicator, with 0 corresponding to lowest rank, and 100 to highest rank (source: World bank database). *goveff* measures perceptions of the quality of public services, the quality of the civil service and its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to its policies (source: World bank database).

4.1 Robustness Check – Panel-Corrected Standard Errors (PCSE)

Given that the baseline specification does not explicitly account for cross-sectional dependence, Panel-Corrected Standard Errors (PCSE) are employed to assess the robustness of the PMG results. Following the recommendation of Beck and Katz (1995), this approach is particularly suitable for panel settings characterized by heteroskedasticity and contemporaneous correlation across units. By correcting the variance–covariance matrix, PCSE produces more reliable and efficient standard errors (Castañeda Rodríguez, 2018). Specifically, the method addresses two key econometric concerns: (i) heteroskedasticity, reflected in unit- and time-specific error variance, and (ii) cross-sectional dependence, arising from contemporaneous correlation of disturbances due to common shocks or spillover effects. The empirical model can be formally expressed as follows:

$$y_{it} = b_0 + b_1X_{it} + b_2D_i + \mu_i + \Lambda_t + u_{it} \quad (3)$$

where X_{it} represents the independent determinants for i at time t ; D_i is a dummy variable in the model used to group economies and/or deviations in the empirical data; μ_i represents individual effects; time effects are represented by Λ_t , while u_{it} represents stochastic disturbances. Thus, the model allows for accurate model estimates in the presence of heteroscedasticity and cross-sectional dependence (CSD).

Using the specification described, we estimated the following model:

$$taxrev_{it} = \alpha + b_1eatr_{1it} + b_2eatr_{2it} + b_3law_{3it} + b_4goweffe_{3it} + u_{it} \quad (4)$$

The econometric procedure follows a standard sequential approach. First, cross-CSD is tested. Second, given the presence of CSD, second-generation panel unit root tests are applied to determine the order of integration. Third, the Westerlund cointegration test is conducted to examine the existence of a long-run relationship among non-stationary variables. Subsequently, PMG and MG estimators are employed to estimate long-run and short-run dynamics, while the Hausman test is used to identify the preferred specification. Finally, robustness is assessed using the PCSE approach.

5 Empirical Results and Discussion

The empirical analysis proceeds by examining both the short-run and long-run dynamic interactions among EATR, $EATR^2$ (its squared term), government effectiveness, rule of law, and tax revenue. Given the availability of EATR data, the panel covers nine EU economies over the period 2004–2023. As a preliminary step, CSD is tested using the Pesaran CD test. The results, reported in Table 1, reject the null hypothesis of cross-sectional independence for EATR, $EATR^2$, government effectiveness, and tax revenue, indicating the presence of cross-sectional dependence in the panel. Such interdependencies are consistent with the high level of economic and institutional integration within the EU, which generates spillover effects across member states (Glavaški et al., 2022). Given the presence of cross-sectional dependence, the second-generation Pesaran (2007) CIPS panel unit root test was applied. The results indicate that the null hypothesis of a unit root cannot be rejected at levels, implying that EATR, $EATR^2$, government effectiveness, rule of law, and tax revenue are non-stationary in levels. However, when first differences are considered, the null hypothesis of non-stationarity is rejected for all variables, confirming that they are stationary in the first differences (Table 1). Considering the detected cross-sectional dependence, cointegration was examined using the robust Westerlund test. The test results reject the null hypothesis of no cointegration, thereby supporting the existence of a long-run equilibrium relationship among the variables. Given the properties of the data, both the PMG and the MG estimators are suitable for estimating the dynamic panel model. The PMG estimator allows for heterogeneous short-run dynamics and adjustment speeds across economies while imposing homogeneity on the long-run coefficients, whereas the MG estimator permits full heterogeneity in both the short and long run. This framework is well suited to the structure of EU economies, which may differ in short-term responses

but may share common long-run fiscal relationships. Accordingly, both estimators are applied, and the appropriate specification is subsequently determined based on formal testing procedures (Table 2).

Table 1: Pesaran CD test, Pesaran CIPS test and Westerlund cointegration test.

	Pesaran CD test	P -values	Lags	CIPS test; level	P -values	CIPS test; first differences	P -values	Westerlund cointegration test	P -values
Sample: 9 EU economies; period 2004–2023									
Tax revenue	3.23	0.001	0	-0.821	0.206	- 3.136	0.001	Gt -2.357	0.001
			1	-0.394	0.347	- 0.278	0.000		
			2	1.518	0.936	0.475	0.000		
EATR	11.35	0.000	0	-2.023	0.022	- 1.656	0.049	Ga -0.778	0.000
			1	-0.276	0.391	- 1.803	0.036		
			2	-1.088	0.138	- 2.421	0.008		
EATR ²	13.60	0.000	0	-2.253	0.012	- 2.147	0.016		
			1	-1.466	0.071	- 2.542	0.006		
			2	-2.033	0.021	- 1.862	0.031		
Government effectiveness	-2.32	0.020	0	-0.430	0.334	- 0.193	0.023	Pt -2.745	0.000
			1	0.700	0.758	1.829	0.006		
			2	0.703	0.759	2.740	0.007		
Rule of Law	-0.86	0.391	0	-1.902	0.029	- 2.271	0.012	Pa -0.385	0.002
			1	-1.262	0.103	- 0.343	0.006		
			2	1.836	0.967	0.078	0.031		

Source: Authors' own calculations based on Stata 15.

The MG estimator does not yield evidence of a statistically significant long-run relationship between EATR, EATR², government effectiveness, and rule of law on tax revenue. By contrast, the PMG estimates indicate a positive and statistically significant ($p < 0.05$) long-run relationship between tax revenue and EATR, while the negative coefficient on the squared term (EATR²) supports the existence of a Laffer curve (confirmation of the Hypothesis H1). Based on the PMG long-run estimates, the implied revenue-maximizing EATR is approximately 16.8%, calculated as $\hat{\tau} = -\beta_1/(2\beta_2)$, where β_1 and β_2 denote the coefficients on EATR and

its squared term (EATR²), respectively. This represents the turning point of the estimated Laffer-type relationship, beyond which further increases in the effective capital tax burden are associated with declining tax revenues. The result provides a clear policy-relevant threshold for tax design within the analyzed EU economies. Government effectiveness and the rule of law also enter positively and significantly ($p < 0.05$), reinforcing the role of institutional quality in sustaining public revenues. The Hausman test ($p = 0.5959$) favors the PMG specification, indicating that the restriction of homogeneous long-run coefficients is not rejected, an outcome consistent with a common monetary framework in the euro area combined with coordinated, albeit heterogeneous, national tax policies.

Table 2: PMG and MG estimator results for homogeneous coefficient for 9 EU economies for the period 2004-2023.

Source: 9 EU economies for period 2004 to 2023.									
Dependent variable: Tax revenue		Long-Run (θ)		Error-Correction (Φ_i)		Constant		Short-Run Equilibrium	
		Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
MG	EATR	13.465	0.358	-	0.000	1.501	0.960	-	0.244
	EATR ²	-0.607	0.334					2.494	0.227
	Government effectiveness	0.140	0.590					0.068	0.767
	Rule of Law	-0.732	0.087					0.014	0.551
PMG	EATR	1.145	0.050	-	0.010	3.722	0.031	-	0.021
	EATR ²	-0.034	0.039					3.366	0.024
	Government effectiveness	0.249	0.000					-	0.077
	Rule of Law	0.212	0.000					0.090	0.052
Hausman test		χ^2				p-value			
		2.78				0.5959			

Source: Authors' own calculations based on Stata 15.

Table 3: PMG and MG estimator results for heterogenous coefficient for 9 EU economies for the period 2004-2023.

Source: 9 EU economies for the period 2004 to 2023												
PMG	Error-Correction		EATR		EATR ²		Government effectiveness		Rule of law		Constant	
	Coef.	<i>p</i> -value	Coef.	<i>p</i> -value	Coef.	<i>p</i> -value	Coef.	<i>p</i> -value	Coef.	<i>p</i> -value	Coef.	<i>p</i> -value
High institutional quality												
Denmark	-0.782	0.000	3.155	0.067	-0.046	0.006	0.457	0.018	0.673	0.036	16.141	0.026
Netherlands	-0.421	0.050	1.168	0.096	-0.022	0.019	0.037	0.007	-0.143	0.312	0.266	0.776
Sweden	-0.667	0.026	4.771	0.042	-0.112	0.035	0.014	0.005	0.092	0.048	2.641	0.324
Medium institutional quality												
Estonia	-0.522	0.018	-2.799	0.024	-0.099	0.117	0.174	0.034	0.083	0.048	4.873	0.347
Portugal	0.047	0.006	0.124	0.039	-0.002	0.052	0.026	0.089	0.100	0.048	-0.423	0.073
Czech Republic	-0.073	0.018	0.039	0.077	-0.006	0.043	0.074	0.061	0.038	0.062	0.159	0.790
Low institutional quality												
Greece	-0.126	0.037	-0.281	0.659	0.005	0.665	-0.020	0.782	-0.081	0.385	1.967	0.175
Bulgaria	-0.149	0.024	-0.581	0.586	0.022	0.576	-0.054	0.209	-0.054	0.625	1.498	0.306
Romania	-0.552	0.000	-19.959	0.033	0.543	0.029	-0.113	0.001	0.010	0.008	6.381	0.212

Source: Authors' own calculations based on Stata 15.

In line with the Hausman test results, the PMG estimator is retained as the efficient specification, therefore cross-country heterogeneity in short-run coefficients and error-correction terms, are reported in Table 3. The error correction term is negative and statistically significant in all observed economies, confirming the existence of a long-run equilibrium and validating the PMG framework. The speed of adjustment varies considerably across countries. Denmark and Sweden, representing economies with high institutional quality, exhibit the fastest adjustment toward the long-run equilibrium (75.2% and 66.7%, respectively). The higher speed of adjustment observed in these economies may reflect stronger institutional capacity, more efficient tax administration, and higher levels of compliance, which facilitate a faster correction of short-run deviations from the long-run equilibrium.

In high institutional quality economies (Denmark, the Netherlands, and Sweden), the results provide the strongest evidence of a Laffer-type relationship. The coefficient on EATR is positive and statistically significant (3.155, 1.168, 4.771; respectively), whereas the squared term (EATR^2) is negative and significant (-0.046, -0.022, -0.112; respectively). This confirms a concave revenue–tax relationship, consistent with the existence of a revenue-maximizing tax rate. Moreover, government effectiveness and rule of law display positive and statistically significant effects in Denmark and Sweden, indicating that stronger institutional frameworks enhance tax compliance and revenue performance. These findings suggest that high-quality economies can sustain relatively higher EATR without triggering revenue erosion, implying an outward shift of the Laffer curve and a higher revenue-maximizing threshold (Hypothesis H1).

The medium institutional quality group (Estonia, Portugal, and the Czech Republic) exhibits a more heterogeneous pattern. Portugal shows evidence consistent with a Laffer structure, as the linear EATR term is positive and significant (0.124) and the quadratic term negative and marginally significant (-0.002). The results for the Czech Republic indicate the presence of nonlinear revenue dynamics, although the linear component is relatively modest. In contrast, Estonia displays a negative and significant linear term (-2.799), suggesting proximity to or positioning beyond the revenue-maximizing rate. Institutional indicators are less robust in this subgroup, implying that governance quality plays a limited role in shaping revenue responsiveness to capital taxation. Overall, the Laffer mechanism appears present but structurally weaker and more sensitive to governance constraints.

In low institutional quality economies (Greece, Bulgaria, and Romania), the revenue response to EATR is weakest and least stable. Greece and Bulgaria show no statistically significant relationship between EATR and revenues. Romania, however, presents a negative and significant coefficient for EATR (-19.959) and a positive coefficient for its squared term (0.543), suggesting a convex relationship between capital taxation and tax revenues. This result indicates that increases in capital taxation are initially associated with declining revenues, reflecting a pattern that differs from the concave Laffer-type relationship observed in some other economies. Such a pattern may be associated with weaker compliance, higher levels of informality, and institutional inefficiencies that limit the effectiveness of capital taxation. Institutional indicators in this group are generally insignificant, reinforcing the interpretation that weak governance structures undermine fiscal capacity.

Overall, the findings provide empirical support for Hypothesis H2, indicating that institutional quality conditions the revenue effects of capital taxation in both the short- and long-run. Higher governance effectiveness and rule of law are associated with greater revenue responsiveness, whereas weaker institutional environments appear to constrain fiscal capacity.

5.1 Robustness check (PCSE)

To verify the stability of the findings, a robust analysis is conducted using the PCSE estimator. The preceding results indicate that EATR, $EATR^2$, government effectiveness, and the rule of law are non-stationary but cointegrated, while the panel exhibits heterogeneity and cross-sectional dependence. Under such conditions, conventional panel estimators may yield inefficient inference. Beck and Katz (1995) advocate the PCSE approach in panels characterized by heteroskedasticity, autocorrelation, and contemporaneous correlation across units. Accordingly, PCSE is implemented to examine whether the main results remain robust to alternative variance-covariance corrections.

The PCSE estimates (Table 4) reinforce the baseline PMG results, confirming a positive and statistically significant long-run relationship between EATR and tax revenue. Quantitatively, an increase in EATR (0.226 ; $p < 0.05$) is associated with higher revenue performance across EU economies over the 2004–2023 period. The negative and significant coefficient on the squared term, $EATR^2$ (-0.008 ; $p < 0.05$)

provides robust evidence of a Laffer-type nonlinearity, indicating diminishing marginal revenue effects at higher effective tax rates. Institutional quality, proxied by government effectiveness and the rule of law, also exerts a positive and statistically significant influence (0.300 and 0.146, respectively; $p < 0.05$), underscoring the role of institutional strength in sustaining fiscal capacity.

Table 4: Results estimated using the PCSE method for 9 EU economies from 2004 to 2023 to check the robustness of the results.

Dependent variable: Tax revenue	Robust check – 9 EU economies; period 2004-2023		
	Coefficient β'_i	Standard error	p -value
EATR	0.226	0.291	0.037
EATR ²	-0.008	0.007	0.029
Government effectiveness	0.300	0.049	0.000
Rule of law	0.146	0.054	0.007
Cons	11.541	1.966	0.000
R ²	0.3408		
Wald chi2	631.60		
Number of obs.	177		

Source: Authors' own calculations based on Stata 15.

5.2 Limitations

Despite its contributions, this analysis is subject to several limitations. First, the relatively small cross-sectional dimension ($N = 9$) may limit the generalizability of the findings and increase the sensitivity of the results to country-specific characteristics. Second, while the PMG and MG estimators allow for heterogeneity in short-run dynamics, they rely on assumptions that may not fully capture structural differences across EU economies. In particular, both estimators are potentially affected by cross-sectional dependence arising from common shocks and strong economic interlinkages within the EU, which may bias the estimated coefficients if not explicitly accounted for. To partially mitigate this issue, robustness checks were conducted using PCSE, which help control for cross-sectional correlation and heteroskedasticity. Future research could address these limitations by extending the sample to a larger set of countries and by applying more advanced panel techniques that explicitly account for cross-sectional dependence. Although the analysis provides evidence of heterogeneous patterns in the tax–revenue relationship across institutional contexts based on coefficient comparisons, a formal statistical test of coefficient equality across country groups (e.g., Wald tests) could not be

implemented due to limitations related to model specification within the dynamic panel framework. Therefore, differences across institutional groups are interpreted based on the magnitude and statistical significance of the estimated coefficients.

6 Conclusion

This paper shows that the relationship between capital taxation and public revenues in the selected nine EU economies is nonlinear and institutionally conditioned. The PMG estimates indicate a positive long-run effect of the EATR on revenues and a negative coefficient on its squared term (EATR^2), consistent with a concave Laffer-type relationship. The significant error-correction term confirms stable long-run equilibrium with heterogeneous short-run adjustments across countries. The analysis further identifies a revenue-maximizing EATR of approximately 16.8%, providing a clear policy-relevant threshold for capital taxation in the studied EU economies.

The findings further suggest that institutional quality influences the strength and pattern of the revenue response. In high-quality economies such as Denmark, the Netherlands, and Sweden, stronger governance frameworks are associated with greater revenue resilience and a more conventional concave Laffer-type relationship between capital taxation and tax revenues. In contrast, in lower-quality institutional environments such as Romania, institutional constraints appear to limit fiscal capacity and weaken the effectiveness of higher capital taxation, consistent with the convex revenue patterns identified in the empirical results. Medium-quality economies exhibit intermediate and more heterogeneous dynamics.

From a policy perspective, the findings suggest that the effectiveness of capital taxation depends critically on institutional quality. In well-governed economies, moderate increases in effective capital taxation may remain revenue-supportive. In contrast, in weaker institutional environments, raising tax rates alone is unlikely to improve revenues, highlighting the need to strengthen tax administration, enforcement, and legal frameworks. These results imply that tax policy design should be adapted to country-specific institutional conditions rather than applied uniformly across economies.

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THE HIDDEN CARBON COST OF SHORT-FORM VIDEO AI: EXAMINING THE SUSTAINABILITY PARADOX IN SOCIAL MEDIA MARKETING

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This study investigates the sustainability paradox inherent in AI-driven short-form video marketing, where the rapid adoption of generative tools (e.g., Runway, Pika, Sora) increasingly conflicts with corporate Net Zero commitments. Drawing on a systematic literature review (2019-2026) at the intersection of AI ethics, environmental science, and marketing, alongside scenario-based carbon modeling, the analysis demonstrates that video generation consumes approximately 30 times more energy than image creation. Estimates indicate that a mid-sized marketing team generating 2,500 AI videos annually can emit up to 325.5 kg CO₂ - a hidden environmental cost largely obscured by decentralized "shadow AI" practices and the lack of AI-specific sustainability metrics in current KPIs. To address this reporting gap, particularly in light of expanding Scope 3 disclosure requirements under the EU CSRD, the paper introduces the Carbon Per Mille (C-CPM) indicator. By proposing algorithmic greenwashing as a conceptual lens, this research provides an initial academic assessment of the carbon footprint of AI video generation and advocates for the integration of carbon-aware operational strategies.

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1 Introduction

In the contemporary digital landscape, short-form video has established itself as a dominant channel for digital interactions and consumer engagement (Luo et al., 2025). Industry reports indicate that short-form videos currently deliver the highest return on investment (ROI) for marketers, with 83% of professionals actively incorporating them into their campaigns (HubSpot, 2025). While public discourse occasionally reduces platforms like TikTok to simplistic entertainment, digital ethnographic research highlights that they actually host complex, platform-specific communicative forms and cultural artifacts that drive profound engagement (Schellewald, 2021). The specific features of short-form video content - such as usefulness, ease of use, and entertainment value - act as powerful stimuli that significantly enhance consumer trust and subsequent purchase intentions (Luo et al., 2025). From a big data perspective, these formal and content-related characteristics play a critical role in increasing consumer engagement, which explains the format's massive market share (Xiao et al., 2023).

The rapid proliferation of this format is increasingly propelled by the integration of Artificial Intelligence (AI) into content production processes. AI has moved beyond the experimental phase to become a central component of modern marketing strategies and research agendas (Mustak et al., 2021). Generative AI applications have significantly advanced targeting, personalization, content creation, and ad optimization capabilities (Gao et al., 2023; Somov et al., 2025). These tools spread rapidly because they verifiably increase management productivity and operational efficiency across multiple industries (Garg et al., 2024). However, this accelerated adoption also brings serious ethical and operational challenges. The opacity of computational advertising and highly personalized, AI-generated content raises significant concerns regarding manipulation, biases, and misleading claims (Gao et al., 2023; Huang & Rust, 2021; Najafloo et al., 2025; Szeberényi et al., 2025).

The intersection of AI-driven video marketing and corporate sustainability creates a severe, yet largely invisible, paradox. As marketing departments scale up the production of short videos relying on highly energy-intensive generative AI tools, a significant portion of the resulting carbon emissions remains completely unaccounted for in corporate Net Zero commitments.

Marketing professionals significantly exacerbate this lack of transparency by bypassing central IT infrastructure and official procurement protocols to utilize decentralized, cloud-based AI tools. This practice, identified in the literature as 'Shadow AI' (Silic et al., 2025), obscures the true scale of the carbon footprint associated with content creation. Addressing these hidden emissions is no longer merely an ethical or theoretical dilemma: the latest directive from the European Commission (2024) under the CSRD (Corporate Sustainability Reporting Directive) mandates comprehensive Scope 3 emissions reporting under ESRS E1, within which cloud-based AI usage constitutes a reportable source. No AI- or digital-specific sub-category is currently defined in the standard, yet this places immediate legal and compliance pressure on organizations.

To resolve this theoretical and practical gap, this study examines the sustainability paradox of AI-driven short-form video marketing by answering the following research questions:

- **RQ1:** To what extent does the application of generative AI tools in short-form video production contribute to unaccounted Scope 3 carbon emissions in corporate ESG reports, and how does the use of "shadow AI" amplify this reporting gap?
- **RQ2:** How do the carbon costs of AI video content creation differ across model architectures, and to what extent can a carbon cost-based indicator operationalize sustainable marketing goals?
- **RQ3:** To what extent can carbon-aware operational strategies - including renewable energy-based scheduling and model compression techniques - reduce the environmental costs of AI video generation without sacrificing marketing effectiveness?

2 Theoretical Background

2.1 The Energy Demand of Video-Generating AI

Beyond representing a technological shift, the rapid expansion of AI systems marks a global ecological turning point. This trajectory has been shaped by the 'Red AI' paradigm described by Schwartz et al. (2019), whereby performance improvements are pursued primarily through scaling computational resources rather than

algorithmic efficiency. The scale of this tendency is illustrated by Strubell et al. (2019), who found that the complete research, development, and training process of a large language model can generate carbon emissions equivalent to the lifetime emissions of five automobiles. Pimenow et al. (2024) further highlight that the aggregate energy consumption of AI has reached such a critical level that it substantially threatens the achievement of international climate targets (Net Zero) if efficiency improvements do not keep pace with the volume of usage. Crucially, the ecological consequences of this paradigm extend beyond training: although model training emissions are expected to stagnate due to hardware optimisations, the widespread everyday use (inference) of AI systems is becoming the primary and fastest-growing operational source of carbon emissions (Patterson et al., 2022). This paradigm shift is evidenced by the measurements of Chien et al. (2023), which demonstrate that the aggregate carbon emissions derived from mass user queries of generative AI systems can exceed the ecological footprint of the model's original training by up to 25 times in a single year. Underpinning the aggregate carbon footprint of AI infrastructure are both the physical energy demands of hardware and the regional carbon intensity of supporting electricity grids (Kirkpatrick, 2023). This trend is further confirmed by Yu et al. (2024), whose comprehensive examination of 79 prominent AI systems between 2020 and 2024 underscores both the scale of aggregate emissions and the persistent lack of industry-wide transparency - notably, the authors were themselves compelled to rely on estimates, as most companies do not publicly disclose precise operational data.

Empirical energy analyses of generative systems have proven that multi-purpose and visual tasks consume orders of magnitude more power than simple text generation; image generation alone is nearly 60 times more energy-intensive than text-based tasks (Luccioni et al., 2023).

The disparity between generative modalities is dramatic: while the energy requirement for a simple text-based query is minimal, the resource intensity of visual content production increases by orders of magnitude rather than linearly. Measurements by Delavande et al. (2025) confirm that video generation processes exhibit an average energy consumption at least 30 times higher than that of generating static images (and almost 2000 times higher than simple text responses) - a conservative estimate corroborated by a large-scale benchmark study across 46 models, in which certain configurations showed energy differences exceeding 100×

between video and image generation (Chung et al., 2026). This finding is consistent with the data from Luccioni et al. (2023) and highlights how the shift toward video-centric marketing tools fundamentally overrides previous emission estimates for the digital sector.

The generation of short-form videos amplifies this effect even further, placing it among the most wasteful operations. During the inference phase of deep learning models, calculating and maintaining the temporal consistency between video frames places an extreme burden on graphics processing units (GPUs) (Desislavov et al., 2021). The spatiotemporal mechanisms of text-to-video diffusion models inherently require a substantial volume of floating-point operations (FLOPs) compared to traditional image generation (Wu et al., 2022). Furthermore, these modern systems are built on multi-billion parameter text-to-image (T2I) architectures, which are supplemented with complex spatiotemporal modules and extra decoders to achieve continuous motion and high visual quality, thereby non-linearly increasing energy consumption (Singer et al., 2022). Green AI fundamentally seeks to embed sustainability considerations directly into the lifecycle of algorithms. The theoretical framework of Alzoubi and Mishra (2024) emphasizes that, alongside software efficiency and hardware optimization, the introduction of transparent measurement metrics is essential for mitigating environmental impact.

2.2 Algorithmic Greenwashing and ESG Shortcomings

Despite the exceptionally high environmental burden of generative video models, a critical "governance gap" exists within organizations, as there is a complete lack of sustainability and accountability metrics regarding everyday AI use (Benbya et al., 2021). Exploiting this opacity, companies increasingly resort to sophisticated forms of greenwashing, which in modern corporate communication is often based on selective disclosure and the structural omission of inconvenient facts (Montgomery et al., 2023).

This is particularly relevant in the information and communication technology (ICT) sector, where companies often frame their digital developments as sustainable and 'green' CSR initiatives, while obscuring the substantial infrastructural impacts of the underlying data centers and algorithms (Famularo, 2023). This practice leads to the phenomenon of "algorithmic greenwashing". At the operational level, this is made

possible by the fact that current Environmental, Social, and Governance (ESG) frameworks are often too generic and fail to specifically capture the complex environmental harms caused by AI technologies (Sætra, 2021). Furthermore, current sustainability indices often simply balance positive and negative impacts, enabling companies to appear sustainable without genuinely adopting environmental values (Horváth, 2023). Under the GHG Protocol, SaaS-based AI video generation constitutes a Scope 3, Category 1 emission source (Purchased Goods and Services) for the end-user organisation (WRI & WBCSD, 2011), meaning it falls within the mandatory reporting boundary established by CSRD's ESRS E1 standard. As a result, companies and their marketing departments can omit the massive carbon footprint originating from AI video generation from these indirect emissions reports with impunity and apparent transparency, thereby maintaining the illusion of Net Zero compliance (Sætra, 2021). Addressing this gap requires not only regulatory pressure but purpose-built measurement tools that embed environmental costs into the same decision layer as financial KPIs - a need this study addresses through the Carbon Per Mille (C-CPM) metric introduced in Section 4.3.

3 Methodology

The present study is built on a two-pillared methodological framework: a systematic literature review and scenario-based carbon modeling.

3.1 Systematic Literature Review

To theoretically ground the problem, a systematic literature review was applied, which allows for the synthesis of the latest findings in rapidly evolving, interdisciplinary fields - in this case, artificial intelligence, environmental science, and marketing strategy (Snyder, 2019). The aim of the review was to explore the conceptual relationships between "Red AI," content creation, and algorithmic greenwashing.

The literature search was conducted across Scopus, Web of Science, and Google Scholar using keyword combinations such as: ('generative AI' OR 'AI video generation') AND ('carbon footprint' OR 'energy consumption' OR 'sustainability') AND ('marketing' OR 'social media'). The search was limited to publications issued between 2019 and 2026. An initial pool of 152 sources was identified, of which 37

were retained following screening by title, abstract, and full-text relevance. Sources were excluded if they addressed AI energy consumption exclusively at the hardware infrastructure level without relevance to end-user organizational contexts.

Beyond this core SLR corpus, the study incorporates additional contextual references - including sources on consumer behavior, marketing frameworks, regulatory standards, and organizational governance - that were identified through targeted citation searches and were not part of the original systematic protocol.

3.2 Scenario-Based Carbon Modelling

Since precise architectural and energy consumption data for the most popular closed-source short-video-generating AI platforms (such as Runway or Pika) are currently not publicly available, the study employs scenario-based carbon modeling rather than direct measurements. The calculations are based on the methodology developed for quantifying the hardware energy consumption (GPU type, runtime) and carbon emissions of machine learning models (Lacoste et al., 2019).

To determine the parameters, the empirical benchmarks of Luccioni et al. (2023) regarding generative AI systems (especially multi-purpose and visual models) were utilized. The tracking and validation of the energy and carbon footprint of deep learning models is supported by the Carbontracker framework and the logic of similar open-source predictive tools (Anthony et al., 2020). The ML CO₂ Impact Calculator algorithm was applied to calculate explicit uncertainty bands and determine the final CO₂ equivalent (kg) (Schmidt et al., n.d.; Lacoste et al., 2019).

During carbon modeling, it is essential to consider the infrastructural background of software computations. For cloud providers, the use of location-based and time-specific marginal emission data is critical, as the emissions of AI models can vary significantly based on the geographical location of the serving data centers (e.g., the carbon intensity of the grid) (Dodge et al., 2022). Accordingly, three scenarios (optimistic, moderate, pessimistic) were developed for energy intensity, incorporating various model scales and respective power grid mixes (e.g., average EU and US grids). Adopting a multi-scenario approach accounts for the inherent variability in regional grid intensities, thereby ensuring methodological transparency. For regional and time-specific marginal emission data, the study draws on Chien et

al. (2023), whose carbon-aware scheduling principles also constitute one of the main pillars of the mitigation strategies proposed in Section 4.3.

4 Results

Building on the theoretical framework and methodology presented earlier, this chapter answers the established research questions (RQ1-RQ3) through scenario-based modeling, quantifying the environmental burdens of short-form video generation, and formulating proposed solutions.

4.1 The "Shadow AI" Phenomenon and Establishing the SME Scenario (RQ1)

The corporate proliferation of generative AI tools has created a new, critical risk factor: the phenomenon of "Shadow AI" (Silic et al., 2025). Shadow AI practices - whereby decentralized individual subscriptions remain invisible to both corporate IT oversight and financial controlling - effectively exclude energy consumption from the scope of sustainability reporting. As a result, the associated emissions are not merely unaccounted for, but remain theoretically unmeasurable within current corporate reporting systems: Shadow AI thus constitutes one of the most critical blind spots in Scope 3 disclosure.

Although the training and maintenance of generative models are conducted by multinational technology companies, the environmental burdens of the associated cloud-based infrastructure (SaaS) directly fall upon the end-users. The SME sector forms the backbone of the global economy, and industry data confirm that small firms face the highest concentration of Shadow AI: at companies with 11-50 staff, 27% of employees actively use unsanctioned AI tools (Silic et al., 2025). Operational security data further reveal an average of 269 active shadow AI applications per 1,000 employees in this segment, indicating that individual users typically rely on multiple tools simultaneously (Reco, 2025). Given this disproportionate exposure, the micro-level modeling of this segment is essential for understanding macro-level ecological impacts.

To contextualize these impacts, we model a representative small and medium-sized enterprise (SME) scenario. In this framework, a two-person marketing team utilizes text-to-video (T2V) models daily for social media campaigns. Including tests, flawed prompts, and rejects, the team generates 10 short videos per day, which translates to 2,500 AI video generations annually, assuming an average 250-day working year.

4.2 Quantifying the Hidden Carbon Footprint

To calculate the physical environmental burden of the above 2,500 generations, we apply the validated logic of ecological footprint tracking systems (Budennyy et al., 2022), based on the following simplified formula:

$$CO_2(kg) = (E_{video} * N) * PUE * CI$$

The variables are determined based on the literature:

E_{video} : The electricity consumption of video generation. The energy demand of diffusion models is primarily determined by the resolution, the video length, and the number of denoising steps (Li et al., 2024). Relying on Delavande et al. (2025), the baseline consumption of generating a 10-second, high-resolution video was set at 0.15 kWh. This value represents a conservative estimate specifically for closed-source commercial platforms such as Runway, Pika, and Sora, for which no public energy data are available; open-source, lightweight models can operate at substantially lower consumption levels, as discussed in Section 4.3.

N: 2,500 generations/year.

PUE (Power Usage Effectiveness): The infrastructural and cooling multiplier of data centers, which is an industry average of 1.55 (Uptime Institute, 2022, as cited in Bouza et al., 2023).

Based on the calculation $(2,500 * 0.15 \text{ kWh} * 1.55)$, the team's annual "Shadow AI" video production alone generates 581.25 kWh of extra electricity consumption.

Determining the associated actual CO₂ emissions (Carbon Intensity, CI) presents a significant challenge. While major technology providers driving state-of-the-art video generation platforms (e.g., OpenAI's Sora on Microsoft infrastructure, Veo/Lumiere on Google Cloud, Runway, and Luma) publicly commit to corporate sustainability goals (Karaarslan & Aydın, 2024; Li et al., 2024), they treat the exact geographical locations and real-time energy mixes of their inference data centers as proprietary business secrets. This structural opacity (Famularo, 2023) makes it impossible to determine the precise grid carbon intensity for specific user requests. To address this uncertainty, we applied three distinct regional grid scenarios (Dodge et al., 2022) to the estimated annual consumption of 581.25 kWh, as detailed in Table 1:

Table 1: Annual Carbon Emission Scenarios for the SME Shadow AI Model (581.25 kWh/year)

Scenario	Energy Mix / Region	Grid Carbon Intensity (CI)	Estimated Annual Emissions
Optimistic	Renewable energy dominant	~20 g CO ₂ /kWh	11.6 kg CO ₂
Moderate	Average grid intensity	~230 g CO ₂ /kWh	133.7 kg CO ₂
Pessimistic	Fossil-heavy (e.g., coal baseline)	~400 g CO ₂ /kWh	232.5 kg CO ₂

Note: Grid carbon intensity (CI) values are based on regional scenarios by Dodge et al. (2022). The pessimistic value represents a conservative lower bound, as fully coal-dependent grids can reach 600–900 g CO₂/kWh. Estimated annual emissions are authors' calculations.

Since estimates from AI energy metering software and static models can carry a margin of error of up to 40% (Fischer, 2025), we must assign an explicit uncertainty band of $\pm 40\%$ to this calculation. This means that, in a pessimistic case, the "Shadow AI" activity can result in up to 325.5 kg CO₂ of invisible annual emissions for a single small marketing team, which is equivalent to driving an average gasoline-powered car for approximately 3,055 kilometers - completely missing from the company's ESG reports.

4.3 Green Marketing KPIs and Guidelines (RQ2 & RQ3)

The transition toward carbon-aware marketing requires metrics that translate environmental impact into the language of business analytics (Alzoubi & Mishra, 2024). To meet this need, we introduce the Carbon Per Mille (C-CPM) indicator. This metric intentionally mirrors the traditional Cost Per Mille (CPM) structure -

with the 'C-' prefix ensuring clear differentiation in analytics dashboards - to elevate sustainability to the same decision-making priority as financial efficiency. By linking the carbon cost of content production with actual platform engagement, C-CPM enables the optimization of marketing ROI on both ecological and financial grounds. Formally, the metric is defined as follows:

$$C - CPM = \left(\frac{CO_2 g}{Impressions} \right) * 1000$$

where $CO_2(g)$ denotes the total carbon emissions generated during the creation of the content asset, expressed in grams, and Impressions denote the total number of views delivered. Integrating such transparent sustainability reporting not only supports CSRD compliance but also secures a long-term competitive advantage by aligning corporate values with measurable environmental accountability (Eccles et al., 2014).

Addressing RQ3 requires a quantitative evaluation of these reduction potentials. According to the cross-model comparison by Delavande et al. (2025), model selection alone accounts for differences spanning several orders of magnitude. Between a lightweight model (e.g. AnimateDiff, 0.14 Wh/video) and a large-scale architecture (WAN2.1-14B, ~415 Wh/video), there is a nearly 3,000-fold difference in energy consumption, while both are capable of producing short-form video content for marketing purposes. Due to the quadratic scaling of resolution and frame count, halving either dimension alone yields approximately a 4-fold reduction in energy use - a measure immediately applicable during testing and draft generation phases (Delavande et al., 2025; Li et al., 2024). Model compression techniques, particularly quantization, also carry substantial potential: reducing numerical precision from FP32 to INT8 can achieve energy savings of 50-67% without meaningful loss in output quality (Vergallo et al., 2025; Khan et al., 2025). Carbon-aware scheduling - deferring non-time-critical renders to periods when the cloud provider's regional grid relies on low-carbon, renewable energy - offers savings that vary by workload duration and regional energy mix. For short tasks, reductions of 30-80% have been demonstrated in certain regions, while longer workloads yield smaller gains (Dodge et al., 2022). Through the combined application of these three strategies, the achievable emissions reduction - without any sacrifice in marketing effectiveness - can bring the pessimistic SME-scenario estimate of 232.5 kg

CO₂/year down to as little as 20-30 kg annually, representing one of the most actionable operational countermeasures against algorithmic greenwashing.

5 Discussion

The responses to the three research questions collectively expose a systemic paradox at the heart of contemporary marketing practice.

The investigation of RQ1 confirmed that decentralized Shadow AI use represents one of the most critical blind spots in Scope 3 emissions reporting. The SME scenario modeling indicates that a single two-person marketing team may generate up to 325.5 kg CO₂ annually under the pessimistic scenario - emissions that remain entirely invisible to current ESG frameworks and corporate IT governance structures. This opacity is further compounded by the proprietary nature of closed-source generative AI models such as OpenAI's Sora, whose server locations and computational requirements are treated as trade secrets (Liu et al., 2024), as well as by the structural tendency of existing sustainability indices to aggregate positive and negative impacts, thereby enabling organizations to maintain the appearance of compliance without genuinely internalizing environmental values (Montgomery et al., 2023; Horváth, 2023). The exclusion of unmonitored activities from ESG reports is one of the most characteristic manifestations of algorithmic greenwashing - a phenomenon further amplified in the digital advertising market by the rapid proliferation of interactive and immersive content formats (Szeberényi et al., 2025).

The answer to RQ2 was developed through a cross-model comparison of carbon costs and the introduction of the Carbon Per Mille (C-CPM) indicator, which translates those differences into a metric directly comparable to existing financial KPIs, thereby elevating sustainability considerations to the same decision-making priority. This instrument directly addresses the measurement gaps of existing ESG frameworks (Sætra, 2021) and provides an operationalizable structure for Scope 3 compliance under CSRD ESRS E1 - within which cloud-based AI inference is now a mandatory reportable source under European Commission (2024) directives. As van Wynsberghe (2021) observes, the narrative must pivot from "AI for sustainability" toward ensuring the "sustainability of AI" itself - and the C-CPM introduced in this study is precisely what makes that shift measurable.

The findings of RQ3 demonstrated that through the combined application of carbon-aware operational strategies - model size optimization, quantization, and carbon-aware scheduling - the pessimistic scenario estimate of 232.5 kg CO₂/year can be reduced to as little as 20-30 kg annually, without any meaningful sacrifice in marketing effectiveness. This potential cannot be realized automatically, however: genuine mitigation requires institutional commitment and a robust sustainability governance culture (Sharma et al., 2026). On the technological side, parameter-efficient fine-tuning procedures such as SimDA (Xing et al., 2023), combined with the organizational integration of Green AI principles, together constitute the infrastructural foundation upon which carbon-aware marketing strategies can be built (Verdecchia et al., 2023).

Taken together, this research documents a systemic paradox in which the pace of technological adoption far outstrips the development of existing ecological frameworks (Lin, 2025; Cows et al., 2021), while AI tools simultaneously offer practical pathways to increase energy efficiency and support conscious consumption patterns (Bozsik et al., 2025). Regulatory pressure - most notably the climate neutrality targets of the European Green Deal and the challenges of the renewable energy transition (Horváth, 2020; Szeberényi et al., 2024) - signals that what was once an ethical oversight is fast becoming a tangible compliance risk, rendering the adoption of carbon-aware marketing practice not only an ecological imperative but a business necessity as well.

6 Conclusions and Future Research

6.1 Summary and Theoretical Contribution

By quantifying the hidden ecological costs of digital marketing, this research identifies that a single micro-level team can generate between 133.7 kg CO₂ (moderate scenario) and 325.5 kg CO₂ (pessimistic upper estimation) annually through decentralized 'Shadow AI' usage. The upper estimate is equivalent to the electricity consumption of an average European household over a 6-7 week period. These findings illustrate how unmonitored digital activities can undermine broader corporate Net Zero commitments.

Central to the study's contribution is the introduction of the Carbon Per Mille (C-CPM) metric. By drawing an intentional terminological parallel with traditional cost-per-thousand metrics, this indicator facilitates an integrated relationship between marketing performance and environmental accountability. Integrating this parameter into analytics enables marketing ROI to be optimized on both ecological and financial grounds, providing a functional tool for organizations navigating the complexities of CSRD compliance.

6.2 Managerial and Practical Implications

This study offers highly actionable insights for marketing professionals, agency leaders, and corporate compliance teams. First, the identification of the 'Shadow AI' blind spot necessitates an immediate revision of internal IT governance. Marketing departments must audit decentralized, unsanctioned generative AI subscriptions to bring these hidden emissions into Scope 3 ESG reporting boundaries.

Second, the proposed Carbon Per Mille (C-CPM) metric provides a pragmatic tool for digital marketers. By integrating C-CPM into standard analytics dashboards alongside traditional financial KPIs, campaign managers can evaluate content ROI through a dual lens of cost-efficiency and ecological impact. Finally, the findings demonstrate that adopting carbon-aware operational workflows - such as rendering non-time-critical video assets during periods of high renewable grid capacity, or defaulting to computationally lighter models and lower resolutions for draft iterations - can drastically reduce a team's carbon footprint without compromising campaign performance or creative quality.

6.3 Limitations and Future Research

While scenario-based modeling addresses the current lack of primary data, the proprietary nature of commercial AI models remains a constraint on absolute precision. To address these estimation errors, the study employed explicit uncertainty bands (Fischer, 2025); however, future inquiries must prioritize direct collaboration with platform providers to replace estimation models with primary energy consumption data.

Beyond technical data refinement, the robustness of the C-CPM metric should be tested within large-scale corporate campaign environments to ensure its scalability within complex ROI analyses. Furthermore, a critical but less explored direction involves investigating the shifting environmental trade-offs between AI-generated workflows and traditional, human-led productions. As global energy grids transition toward renewables, the carbon-intensity ratio between these two modalities will likely evolve in ways that current static models cannot yet fully encapsulate.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Claude AI and Gemini for language editing, structural refinement, and proofreading. After using these tools, the authors reviewed and edited the content as needed and took full responsibility for the publication's final content.

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EDUCATION TECHNOLOGIES AND INSTITUTIONAL BOUNDARIES: EDUCATION–BUSINESS INTERACTION IN THE CONTEXT OF INDUSTRY 5.0

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This study examines how education technologies influence institutional boundaries in the interaction between formal education systems and business organizations under Industry 5.0. While existing research has largely focused on the pedagogical role of digital learning, less attention has been given to how education technologies reshape the interaction between education and business as an integrated institutional process. Moving beyond their pedagogical function, education technologies are conceptualized here as institutional mediators that redistribute responsibilities for knowledge and skill formation across sectors. Using an institutional–analytical approach complemented by an illustrative case of Georgia, the paper shows that adaptive learning ecosystems expand more actively in contexts where foundational competencies are already present. This suggests that education technologies operate as capability-enhancing mechanisms rather than substitutes for formal education. The findings point to a reconfiguration of education–business interaction characterized by differentiated and context-dependent role distribution. At the same time, they highlight a potential tension between the inclusive aspirations of Industry 5.0 and the selective dynamics of market-driven training systems.

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1 Introduction

The transition from Industry 4.0 to Industry 5.0 reflects not only technological change but a broader reconfiguration of institutional arrangements that shape how knowledge and skills are produced and distributed across sectors. While earlier phases of industrial transformation emphasized efficiency and automation, Industry 5.0 introduces a governance-oriented perspective that places human-centricity, resilience, and societal alignment at the center of economic organization (European Commission, 2021).

This shift highlights the importance of coordination between education systems and business organizations in preparing the workforce for evolving labor market conditions (ILO, 2023). Rather than assuming that education simply responds to technological change, contemporary policy frameworks increasingly stress the need for institutional interaction in shaping workforce readiness (OECD, 2021).

Within this evolving landscape, education technologies have gained prominence as mechanisms that enable more flexible and responsive learning arrangements. Initiatives such as micro-credentials and modular training programs signal an emerging redistribution of responsibility for skill formation across higher education institutions, employers, and private providers (Council of the European Union, 2022).

At the same time, global monitoring efforts caution that the expansion of digital learning does not automatically produce inclusive outcomes. UNESCO highlights the importance of governance and accessibility in shaping how technological integration affects workforce development (UNESCO, 2023).

These developments suggest that the relationship between education and business is increasingly structured through hybrid learning ecosystems rather than through linear knowledge transfer.

Education technologies appear to play a central role in this transformation by enabling adaptive learning pathways that align workforce preparation with changing demands (OECD, 2023). However, emerging evidence indicates that such adaptive

mechanisms operate most effectively when supported by prior competencies and foundational learning structures (World Economic Forum, 2023).

Despite the growing attention to education technologies and Industry 5.0 in policy and academic discussions, the interaction between education systems and business organizations remains insufficiently explored as an integrated institutional process. Existing research tends to examine technological innovation, education systems, and labor market dynamics in relative isolation, while the mechanisms through which education technologies reshape institutional boundaries between these domains receive comparatively limited analytical attention.

This raises an important institutional question: do education technologies generate new capabilities, or do they primarily reshape how existing capabilities are mobilized?

Against this backdrop, this study examines how education technologies influence institutional boundaries in the interaction between higher education systems and business organizations under Industry 5.0.

Research Question

How do education technologies influence institutional boundaries in the interaction between education systems and business organizations under Industry 5.0?

2 Methodology

This study adopts an institutional–analytical approach to examine how education technologies influence the evolving interaction between higher education institutions and business organizations in the context of Industry 5.0.

The analysis is grounded in the premise that contemporary technological transitions are accompanied by shifts in institutional roles related to knowledge production and skill formation. Within this framework, education technologies are treated as the primary analytical focus due to their capacity to support adaptive learning mechanisms that respond rapidly to changing workforce demands.

Rather than viewing education technologies as neutral tools, the study conceptualizes them as institutional mechanisms that shape how responsibilities for skill development are distributed across sectors.

To capture these dynamics, the research combines conceptual analysis with an illustrative case study. Institutional theory is used to interpret how Industry 5.0 influences the interaction between education and business systems, particularly in relation to emerging forms of learning provision such as modular training and micro-credentials.

The Georgian context serves as an analytical case based on selective observation of private training platforms, corporate learning initiatives, and sectoral patterns of skill demand. This approach allows the study to illustrate how education technologies expand within existing labor market structures, particularly in relation to differences in technological intensity and human capital readiness across sectors.

At the same time, the rapid expansion of business-driven training systems creates a growing need for more systematic statistical monitoring of skill formation processes. Comprehensive data on the distribution of training provision across sectors, the frequency of reskilling cycles, and the scale of non-degree-based employment remain limited, both in Georgia and in comparable contexts.

Accordingly, the Georgian case is approached as exploratory and interpretative analysis of observed sectoral patterns based on available data and mapping of existing training providers. The objective is not to establish causal relationships but to identify emerging patterns in the interaction between education systems and business-driven training ecosystems. The patterns identified in the analysis should therefore be interpreted as indicative rather than definitive, while more robust empirical validation remains an important direction for future research.

Through this combined approach, the study provides an analytical perspective on how education technologies influence the redistribution of roles between foundational knowledge production and adaptive skill formation.

3 Institutional Boundaries in Education-Business Interaction under Industry 5.0

3.1 Institutional Context of Education-Business Interaction Methodology

Recent academic and policy discussions increasingly interpret the relationship between education systems and labor markets as an institutional matter rather than a purely pedagogical or technological issue.

The transition toward Industry 5.0 has accelerated this shift by foregrounding the governance dimension of workforce preparation. The European Commission conceptualizes Industry 5.0 as a framework that integrates technological change with broader societal objectives such as resilience and human well-being (European Commission, 2021). This perspective implies that workforce readiness is shaped not only by technological adoption but also by institutional coordination between education providers and economic actors.

International organizations have emphasized this systemic view. UNESCO's work on the future of education underscores the need to preserve education's public function while adapting to changing labor market conditions (UNESCO, 2021). Rather than promoting technological substitution, UNESCO highlights the importance of maintaining institutional stability alongside flexibility.

OECD analyses similarly stress that adaptation to evolving employment structures depends on the interaction between formal education systems and lifelong learning mechanisms (OECD, 2021). More recent OECD work on micro-credentials suggests that emerging certification models are reshaping how competencies are recognized and validated across institutional settings (OECD, 2023).

The European Union's recommendation on micro-credentials further illustrates this trend by encouraging flexible learning pathways delivered across higher education institutions, employers, and private providers (Council of the European Union, 2022). These developments signal an increasing redistribution of responsibility for skill formation.

At the same time, global monitoring efforts highlight potential governance challenges associated with technological expansion in education. UNESCO's Global Education Monitoring Report (2023) emphasizes the need for inclusive and accountable integration of digital learning systems.

Research on education governance also supports this institutional perspective. Studies examining digital platforms and data infrastructures indicate that emerging learning ecosystems increasingly rely on intermediaries that influence decision-making and legitimacy (Nichols & Dixon-Román, 2024; Williamson & Piattoeva, 2021).

Complementary research on EdTech intermediaries suggests that actors operating between public education systems and private market providers play a growing role in shaping how digital learning solutions are adopted and evaluated (Ortegón, 2024).

These insights are reinforced by broader labor market analyses. The World Economic Forum highlights the increasing importance of reskilling mechanisms driven by employers (World Economic Forum, 2023). Similarly, the International Labour Organization underscores the need for inclusive lifelong learning systems capable of responding to structural shifts in employment (ILO, 2023).

Taken together, this literature suggests that the interaction between education and business is evolving from a sequential relationship toward a more integrated arrangement.

3.2 Industry 5.0 and Boundary Reconfiguration

Within this evolving context, Industry 5.0 can be understood as a reconfiguration of institutional arrangements that shape how knowledge and skills are produced and coordinated across sectors (European Commission, 2021).

Historically, universities have functioned as key institutional actors responsible for the production of foundational knowledge and the conferral of epistemic legitimacy through formal qualifications (Marginson, 2019). Firms, in turn, have primarily specialized in firm-specific training aligned with operational needs, while the

provision of broader cognitive foundations has been implicitly treated as a function of the education system (Williamson, 1985).

This division of roles contributed to relatively stable institutional boundaries between education and business.

Institutional theory offers a useful lens for interpreting how these boundaries evolve. Institutions structure authority and responsibility across social domains (North, 1990). Under Industry 5.0, these arrangements become more dynamic as education and business increasingly share roles in workforce preparation.

Already in the early twenty-first century, it was noted that workforce preparation was shifting from a linear model toward a more integrated configuration, in which education and business interact through overlapping institutional roles (Etzkowitz & Leydesdorff, 2000). Firms have gained greater capacity to respond to short-cycle skill demands, while education systems continue to sustain foundational knowledge that supports long-term adaptability (Barnett, 2018).

Importantly, this transformation has generated considerable scholarly and societal interest. Reflecting the reconfiguration of institutional boundaries, it appears at times as complementary, at times as overlapping, and in some cases is interpreted as implying a partial substitution of traditional educational functions by education technologies.

3.3 Education Technologies as Mediating Infrastructures

Within this emerging configuration, education technologies play a central role in shaping how institutional boundaries are negotiated.

By enabling modular learning formats, micro-credentials, and short-cycle training programs, education technologies facilitate more flexible engagement of firms in workforce preparation.

Historically, universities focused on providing foundational knowledge and general competencies, while firms concentrated on role-specific training. Education technologies now enable firms to participate more directly in learning processes

traditionally associated with formal education systems. However, this shift does not imply that education technologies replace the role of higher education.

Research indicates that adaptive training mechanisms are most effective when supported by prior competencies and foundational learning structures developed within formal education (Barnett, 2018).

In this sense, education technologies function not as substitutes but as mediating mechanisms that structure interaction between foundational knowledge production and adaptive skill provision. They allow firms to respond more rapidly to emerging workforce needs while maintaining reliance on the broader cognitive foundations cultivated by higher education institutions.

Consequently, education technologies contribute to a redistribution of responsibilities rather than a displacement of institutional roles. Their significance lies in enabling coordination between stability and flexibility within workforce preparation systems.

Within the context of Industry 5.0, this mediating role becomes particularly important as education and business systems increasingly operate through hybrid arrangements. Education technologies thus shape how institutional boundaries are reconfigured while preserving the continued relevance of foundational education.

4 Education-Business Interaction in Practice: The Georgian Case

In Georgia, the expansion of education beyond universities is most visible within IT and digitally intensive professions, where rapid technological change and persistent skill mismatches generate strong demand for continuous reskilling. However, rather than beginning with institutional actors, it is analytically more appropriate to first examine how reskilling demand is distributed across sectors of the economy. This approach allows for a clearer understanding of why certain sectors become focal points of post-university training ecosystems, while others remain comparatively less integrated into adaptive learning structures.

The Georgian case demonstrates that the emergence of adaptive learning systems is closely associated with sectoral differences in human capital readiness and technological exposure. To capture these dynamics, the analysis draws on sectoral employment data from the National Statistics Office of Georgia (GeoStat), which provides insight into how reskilling demand is distributed across the economy.

Instead of focusing on workforce size as the primary determinant of training provision, the analysis examines how differences in sectoral characteristics, particularly technological intensity and baseline competencies - shape the conditions under which reskilling demand emerges. Table 1 provides an analytical approximation of sectoral patterns of reskilling demand and human capital readiness in Georgia, based on available GeoStat data and observed training dynamics across sectors. The classification reflects relative differences across sectors rather than precise quantitative measurement.

Table 1: Sectoral Patterns of Reskilling Demand and Human Capital Readiness in Georgia

Sector	Relative Employment Significance	Evidence of Reskilling Demand
IT & Digital Services	Low	Very High
Finance & Banking	Medium	Medium-High
Healthcare	Low	Low
Construction	High	Low
Agriculture	Medium	Very Low

Table 1 shows that demand for reskilling does not necessarily follow employment mass. Sectors such as IT and finance exhibit relatively higher levels of reskilling activity despite their smaller workforce shares, while sectors with larger employment bases display comparatively lower levels of adaptive skill upgrading.

These differences are associated with variations in technological intensity and the presence of baseline competencies across sectors. Adaptive learning systems tend to emerge more actively in environments where existing skills facilitate further training, whereas in sectors with lower initial capacity, the expansion of such systems appears more limited.

It is also important to note that, although the IT sector accounts for a relatively small share of total employment, digital competencies are increasingly relevant across multiple sectors. This broader relevance contributes to sustained demand for IT-related training, beyond the boundaries of the sector itself.

Overall, the observed pattern helps explain why post-university learning activities are more visible in innovation-oriented domains, while remaining less developed in sectors with large employment shares.

Table 2 shows that private platforms and corporate academies in Georgia are primarily concentrated in digitally intensive and business-oriented domains. This distribution corresponds with the sectoral patterns observed in Table 1, where reskilling activity is more visible in areas characterized by higher technological exposure.

Table 2: Training Providers in Georgia and Their Sectoral Focus

Provider (Georgia)	Training type	Sectors / domains
Skillwill	Private training platform (courses + certificate)	IT/Tech, project management, short-cycle skills
IT Academy STEP Georgia	Private academy; certification-oriented tracks	Programming, cybersecurity, UI/UX, design
TBC IT Academy	Corporate-funded professional training	Software development, DevOps, Data, IT support
TBC Techschool	Short-cycle programs	Front-end, Back-end, Mobile dev, AI basics
TBC Campus	Business and digital skills training	Digital marketing, Data analysis, entrepreneurship
Bank of Georgia – TB Academy	Private training center	Finance, accounting, taxation
Bank of Georgia – 360 Education	Online platform	Business training and masterclasses
TBC Education	Multi-program ecosystem	Tech and AI learning

Taken together, the two tables indicate that training provision does not closely follow overall employment distribution. Instead, it appears more developed in sectors where existing skills and technological requirements create conditions for continuous upgrading.

At the same time, the presence of corporate academies suggests that some firms increasingly engage in structured training activities within organizational settings. These initiatives extend learning into the workplace, particularly in domains where rapid adaptation is required. In contrast, formal education continues to play a more stable role in providing broader foundational competencies that support long-term skill development.

In this context, the Georgian case points to a differentiated pattern of interaction between education and business. Training systems do not develop uniformly across sectors but are more active where prior capabilities support further skill development, resulting in a more uneven distribution of learning opportunities.

Overall, these patterns suggest that the expansion of adaptive learning systems is shaped not only by technological change but also by existing institutional and human capital conditions. This provides a more grounded understanding of how the relationship between education and business evolves through differentiated and context-dependent adjustments within the broader transformations associated with Industry 5.0.

5 Discussion: Institutional Complementarity under Industry 5.0

The analysis presented in this study suggests that the transition to Industry 5.0 does not dissolve the traditional distinction between education and business but reshapes their interaction into a more differentiated and complementary structure.

As demonstrated in the Georgian case, adaptive learning ecosystems expand selectively in sectors characterized by pre-existing human capital readiness. This indicates that education technologies function not as independent generators of capability but as mechanisms that support the further development of existing competencies. This selective expansion reflects differences in sectoral capacity to absorb and utilize new skills, rather than differences in technological availability alone.

Such dynamics reinforce the continued structural relevance of universities within evolving knowledge ecosystems. While firms gain flexibility in addressing short-cycle skill requirements through private platforms and corporate academies, universities

remain central to the formation of foundational competencies that enable adaptive learning.

From an institutional perspective, this reflects a reallocation of roles rather than their erosion. Businesses increasingly focus on rapid, role-specific skill formation, whereas education systems sustain broader knowledge structures that underpin long-term innovation capacity.

In this context, the distinction between university-based education and private or corporate training ecosystems can be understood in terms of their underlying institutional logics. University-based education remains oriented toward foundational, discipline-based knowledge and long-term learning trajectories, while private and corporate systems focus on applied, role-specific competencies and short-cycle training formats aligned with labor-market demand.

This differentiation becomes particularly relevant in the context of Industry 5.0, where adaptive capacity depends not on the dominance of a single model but on the interaction between them. The Georgian case illustrates how such interaction develops unevenly across sectors, highlighting the importance of institutional coordination.

At the same time, the expansion of adaptive learning systems is not uniform. Training activity tends to concentrate in innovation-intensive domains while remaining more limited in sectors with large employment shares but weaker foundational skill bases.

This uneven diffusion points to a potential tension within the Industry 5.0 paradigm. While the framework emphasizes inclusive and human-centered development (European Commission, 2021), the mechanisms that support rapid adaptation may operate more effectively in already advantaged environments. This tension underscores the importance of governance and coordination in shaping how technological transformation unfolds.

Without such coordination, the reconfiguration of institutional roles may reinforce existing capability differences across sectors and workforce groups. Ensuring that flexibility is balanced with inclusivity therefore becomes a key condition for the sustainable development of learning ecosystems.

6 Conclusion

This study set out to examine how education technologies influence institutional boundaries in the interaction between higher education systems and business organizations under Industry 5.0.

The analysis suggests that technological transformation does not eliminate traditional institutional distinctions but reconfigures them through new patterns of coordination.

Education technologies emerge not as substitutes for formal education but as mediating infrastructures that enable firms to participate more directly in adaptive skill formation while maintaining reliance on foundational knowledge produced by universities.

The Georgian case illustrates how this transformation unfolds in practice. The expansion of private training platforms and corporate academies demonstrates the growing role of business actors in workforce preparation. At the same time, their effectiveness remains dependent on prior competencies rooted in formal education, and their development appears uneven across sectors.

This suggests that the impact of education technologies is conditional rather than autonomous, depending on existing institutional and human capital conditions.

Theoretically, the findings contribute to understanding Industry 5.0 as an institutional transformation that reshapes how responsibilities for knowledge production and skill formation are distributed across sectors.

Rather than dissolving boundaries between education and business, Industry 5.0 renders them more dynamic and context-dependent.

From a policy perspective, the study underscores the importance of maintaining strong foundational education systems alongside investments in adaptive learning mechanisms.

Without such balance, technological transitions may enhance responsiveness without supporting inclusive workforce development.

Ultimately, sustainable adaptation under Industry 5.0 depends on institutional complementarity between stable knowledge production and flexible skill formation. The findings suggest that the expansion of adaptive learning ecosystems appears to be shaped more by pre-existing institutional and human capital conditions than by technological availability alone. This highlights the risk that Industry 5.0-driven transformations may reinforce capability asymmetries unless governance mechanisms actively align flexibility with inclusivity.

7 Directions for Future Research and Policy Implications

The findings of this study suggest that while Industry 5.0 advances a vision of inclusive and human-centered development, adaptive learning ecosystems appear to expand more actively in contexts where foundational competencies are already established. This points to a potential tension between the inclusive aspirations of Industry 5.0 and the selective dynamics of market-driven skill formation.

At the same time, the analysis highlights an important limitation related to the availability and structure of statistical data on skill formation processes. Existing datasets, including those used in this study, provide only partial insight into the distribution of training provision, the frequency of reskilling cycles, and the scale of non-degree-based employment. This constrains the ability to fully capture the dynamics of adaptive learning ecosystems and underscores the need for more systematic and comparable statistical frameworks.

Future research could therefore explore how policy frameworks might ensure that the growth of education technologies contributes to broader workforce inclusion rather than reinforcing existing capability distributions. Comparative studies across national and sectoral contexts would provide valuable insight into how institutional arrangements shape the inclusivity of adaptive learning systems and what

governance mechanisms may be required to align flexibility with equitable access to skill formation.

While this study focuses on a single-country case, it contributes to advancing an institutional perspective on Industry 5.0 by highlighting the redistribution of roles between education systems and business actors. Further research could build on this framework by examining how different governance configurations mediate the balance between foundational education and adaptive training.

Such work is likely to be important for informing policy approaches that support technological responsiveness while maintaining long-term capability development and social cohesion.

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Summary

This study examines how education technologies influence institutional boundaries in the interaction between higher education and business under Industry 5.0. Moving beyond technology-centered interpretations, the analysis conceptualizes Industry 5.0 as an institutional transformation that redistributes responsibilities for knowledge production and skill formation across sectors.

The findings suggest that technological change does not dissolve the distinction between education and business but reconfigures their relationship into a system of complementary roles. Education technologies enable firms to participate more directly in adaptive skill formation while remaining reliant on foundational competencies sustained by formal education systems.

The Georgian case illustrates how this redistribution unfolds in practice, highlighting the expanding role of private and corporate training alongside universities, as well as the uneven development of adaptive learning across sectors. Theoretically, the study advances an institutional interpretation of Industry 5.0 by emphasizing the evolving and context-dependent allocation of responsibilities for knowledge production and skill formation.

From a policy perspective, the findings suggest that investments in adaptive learning need to be accompanied by sustained support for foundational education systems. Without such balance, technological responsiveness may deepen existing capability differences rather than support inclusive workforce development, making governance and institutional coordination central to effective transition strategies.

JUDO AGENTS: A GENTLE WAY TO HYBRID REALITY

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The rapid proliferation of artificial intelligence is generating a plurality of heterogeneous, interacting intelligences within what can be described as Hybrid Reality (HyR): a socio-technical continuum in which humans, cyber-physical systems, artificial agents, and societal structures co-evolve. In this setting, the traditional pursuit of Artificial General Intelligence (AGI) as a monolithic optimizing entity appears increasingly inadequate and potentially destabilizing. The central issue is no longer intelligence itself, but the preservation of systemic integrity, trust, and human sovereignty within the HyR. This paper introduces Judo Agents, a class of socially embedded, AGI-oriented agents designed according to a “gentle” paradigm. Rather than maximizing performance, they incorporate bounded rationality, controlled fallibility, and epistemic humility as foundational features. Inspired by cybernetics and holonic systems, Judo Agents act as co-controllers and integrity sentinels, co-evolving symbiotically with humans. This work redefines research towards relational, trust-based societal capability grounded in safe and transparent human–machine symbiosis.

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1 Introduction

The accelerating proliferation of artificial intelligence (AI) systems is transforming the ontological and operational structure of contemporary societies. We are facing an epochal transformation. Every day we hear news of jobs being lost in favour of some AI application; the lights-out factory is already a reality. Xiaomi recently unveiled its next-generation "dark factory" in the Changping District of Beijing, a facility that represents a decisive leap in "lights-out" manufacturing (Sarthak, 2026; Reg AI, 2026). The entire economic and job-creation process will be impacted by AI developments, with major consequences for geopolitical and social structures. According to FFG (2025): by 2026, over 95% of customer support interactions will involve AI; by 2027, sovereign AI models are expected to be launched in at least 25 countries; by 2028, AI-generated scientific papers will outpace those authored solely by humans in terms of quantity; by 2030, AI is projected to contribute more than \$15.7 trillion to global GDP.

The relationship between humans and machines, although not a new phenomenon by itself, is changing rapidly and significantly like never before. *MoltBook* (Moltbook, 2026) is a social platform where artificial agents interact freely and without specific control; humans are left watching what emerges, if they can understand it at all. Other similar applications, based on the same *Open Claw* technology, even recruit humans to perform tasks in exchange for payment in cryptocurrency, with the tagline capturing the premise: "*AI can't touch grass. You can.*" (Rentahuman, 2026; Schmelzer, 2026).

Even more concerning is the fact that many of the major applications, which are closed and proprietary, are not even fully under the control of their own (human) creators, since the recent results achieved depend more on processes of emergence than on perfectly controllable design and engineering processes (Amodei, 2026). The societal and geopolitical aspects are at some verge as well, as Amodei clearly puts (Amodei, 2026):

"we should arm democracies with AI, but we should do so carefully and within limits: they are the immune system we need to fight autocracies, but like the immune system, there is some risk of them turning on us and becoming a threat themselves."

Thus, we are here in search of some conceivable and sustainable form of this immune system, that must be in equilibrium and under due control.

We are no longer facing isolated tools or narrow intelligent subsystems, but rather a plurality of heterogeneous, interacting intelligences embedded in what can be defined as Hybrid Reality (HyR): a socio-technical continuum in which humans, artificial agents, cyber-physical systems, and institutional infrastructures co-evolve (Perko, 2021; Pirani et al., 2025). HyR is not simply an augmented digital layer superimposed on the physical world. It is a structurally entangled ecosystem in which decisions taken by artificial agents directly influence social and economic processes, while human cognition is increasingly extended and mediated by algorithmic infrastructures.

In this environment, cyber-physical systems (CPS) continuously translate physical states into digital representations and back again, creating a bidirectional flow between material and computational domains. At the same time, blockchain-based and distributed systems should be engineered to function as trust membranes, regulating interactions and ensuring accountability across these interconnected layers (Pirani et al., 2025).

In such a landscape, the classical research trajectory toward Artificial General Intelligence (AGI) appears increasingly inadequate, when it is usually understood as a monolithic, optimizing, human-level or super-human cognitive system. The challenge is no longer simply “how to build more intelligent machines.”. Capabilities of AI will come by themselves and possibly in a rather unforeseeable way as already happened. In this context, the real challenge is: How to preserve systemic integrity, human sovereignty, and relational trust within HyR?

This chapter positions and proposes that the core problem of the coming years (two years, months?) is not the maximization of intelligence and its performance, but a symbiotically governance of intelligence within complex socio-technical systems, recognizing the HyR as major new phenomenon. In this case, human sovereignty is not guaranteed, but at least, in the struggle between human sovereignty and machine sovereignty, a draw may be achieved if symbiosis is pursued instead of confrontation.

To this end, we introduce the concept of Judo Agents, socially embedded, AGI-oriented agents designed according to a “gentle” paradigm. Rather than maximizing performance or imitating idealized human cognition, Judo Agents deliberately integrate bounded rationality, controlled fallibility, and epistemic humility as structural features. They also incorporate reflexive trust construction and holonic embedding, positioning themselves not as dominant optimizers but as context-aware, cooperative components within a broader socio-technical ecosystem. They are not apex optimizers, they do not aim at exceptional and specific capabilities, but they will constitute a weapon towards the complexity of the sustainability of the HyR, that is the sustainable symbiosis between humans and machines. As we will recall in section 2, the control of HyR is hard and still open problem in many respects. Judo Agents, are here conceived, posed, and proposed, in section 3, as a research roadmap for the viable design of the control of the HyR. In brief, Judo Agents are the co-controllers and integrity sentinels within Hybrid Reality we would like to have available very soon.

The research perspective here proposed aim to provide a position that can be used to answer to the following research question (RQ): *How can Hybrid Reality systems be designed and governed to ensure systemic integrity, preserve human sovereignty, and sustain trust among heterogeneous interacting intelligences?*

2 Related works and motivational background

In this section are briefly gathered and recalled the several topics that are concerned in the proposed Judo Agents position. It does not aim to be exhaustive in any respect but at least providing minimal self-consistency to the development to this proposal.

2.1 Hybrid Reality as a socio-technical continuum

In HyR, intelligence is no longer a property of isolated agents. It is an emergent relational capability. HyR can be understood as a multi-layered socio-technical ecosystem in which human cognition, decision-making, and even identity is partially mediated by algorithmic systems, while artificial agents operate autonomously within physical and institutional environments. In this context, cyber-physical systems continuously integrate sensing, computation, and actuation; blockchain or distributed ledger technologies provide trust infrastructures that regulate interactions across domains. HyR is therefore neither virtual reality nor merely digital

transformation; rather, it represents the fusion of physical processes, digital infrastructures, artificial intelligence, and social institutions within a dynamically evolving environment.

Building on Perko's definition (Perko, 2021), HyR can be seen as the space where human and artificial entities interact and co-construct reality, a transitional and unstable phase in which AI becomes an active stakeholder that both shapes and is shaped by human practices. For the purposes of this work, HyR is best defined as a phenomenon (Pirani et al., 2025): an observable and systemic pattern emerging from the convergence of human cognition, intelligent machines, and cyber-physical systems. This convergence shifts the locus of control from centralized governance to distributed and recursive control loops spanning individuals, organizations, machines, regulatory frameworks, and algorithmic markets.

Within this scenario, the perspective of Digital Humanism becomes crucial. Digital Humanism emphasizes that technological development must remain aligned with human values, dignity, autonomy, and democratic principles. Rather than allowing algorithmic infrastructures to silently redefine norms and power structures, Digital Humanism calls for transparency, accountability, and meaningful human oversight (Hahne & Schmoelz, 2026). In HyR, this translates into the need to preserve human sovereignty while enabling beneficial human-machine symbiosis. However, HyR also introduces significant systemic risks, including local over-optimization, opacity of AI decision processes, erosion of trust through automation bias, displacement of human agency, and cascading fragility across interconnected systems. Understanding, modelling, and regulating HyR is therefore essential to ensure that this evolving socio-technical phenomenon remains stable, adaptive, and aligned with human-centered principles.

The open problem with the several existing frameworks on Ethics and AI (Ashby, 2020; 2022) is that it is not clear how they will be implemented and enforced, and mostly if their effects will arrive on time. The HyR and the control framework proposed in Pirani et al. (2025) made a first tentative to leverage Cyber-Systemic and Systems Engineering hardiness to this topic, as recalled in the next subsection.

2.2 Cybernetics 5.0, a ground for safety on adaptation to unexpected and complexity

A proposal to strengthen the penetration of cybernetics principles in engineering has been recently made by Pirani et al. (2025b). *Cybernetics 5.0* was proposed as a transdisciplinary framework designed to reconcile the automation-driven goals of Industry 4.0 with the human-centric, ethical, and sustainable priorities of Industry 5.0. At the heart of this vision is the Holonic Management Tree (HMT), a methodological tool that utilizes holonic structures (entities that function as both independent wholes and integrated parts, see below for more) to manage the inherent complexity of modern Cyber-Physical Systems of Systems (CPSoS). The work Pirani et al. (2025b) proposed a strategic roadmap through 2030, emphasizing the integration of cognitive digital twins, artificial general intelligence, and responsible AI to achieve a harmonious balance between technological efficiency and socio-economic values. A key point was the priority of raising technical community awareness of visions toward human–AI symbiosis and co-evolution, as outlined by Lee (2020).

A still fundamental stance, followed by Pirani et al. (2025b), is "Design for Unexpected" (D4U) principle (Valckenaers & Van Brussel, 2015), which is complementarily used to address the complexity in industrial environments through the following methods:

- **Handling time scarcity and complexity.** Time is a primary generator of complexity in industry because it is a special resource that cannot be conserved or saved for later (Lee, 2009). In production systems, time is not a free variable but is controlled by production targets. The D4U principle addresses this by avoiding "over-commitment," which is noted to stifle controllers and hinder general adaptability and resilience.
- **The role of lazy development.** The core concept of D4U is the support of "lazy development". Rather than attempting to model every detail of a complex system from the outset, this approach specifies only the minimum viable attributes of each entity, deliberately avoiding over-specification. It uses placeholder sub-models that are refined only when specific details or external events impact the system. This form of "laziness" also enables second-order or

meta-level modelling operations, keeping the system adaptable and aligned with an autonomic computing vision (Kephart & Chess, 2003; Zhang et al., 2024).

- **Realization through holonic structures.** The D4U principle is implemented through a holarchical approach, meaning that the controlling system is structured as a hierarchy of holons. A holon, a concept introduced by Arthur Koestler (1968) and since then well-known in intelligent manufacturing (Derigent et al., 2021), is an entity that is simultaneously a whole in itself and a part of a larger whole. A holarchy is therefore an organized structure of nested, semi-autonomous units, each capable of local functioning while contributing to higher-level systemic behaviour. Parts can remain intentionally unspecified, allowing the architecture to evolve and create branches on demand. This enables flexible granularity, with relationships defined only when expansion or reconfiguration is needed.

Pirani et al. (2025b) support the staying "on the crest of the wave" with light, fast, and simple solutions, where the D4U principle avoids the "inescapable swamping" that occurs when using complicated and heavy solutions that consume too much time. This is a concept that the growing ranks of autonomous agents will need to embrace.

While Cybernetics 5.0 and the HMT methodology offer a promising roadmap, key socio-technical challenges remain. In particular, HMT faces both conceptual and practical limitations, especially in the complex construction and continuous refinement of holonic models. As systems evolve, maintaining coherence between design and operational reality becomes increasingly difficult.

Further limitations emerge in automation and digitization. The transition from methodology to fully automated digital tool remains incomplete. HMT is therefore better described as an engineering methodology rather than a ready-to-use software solution, and its systematization across specific industrial sectors is still problematic.

Computational and behavioural constraints also play a role.

New concurrent cybernetics visions provide theoretical frameworks for understanding how recursive optimization leads to the erosion of internal diversity and eventual systemic collapse across various domains, including artificial

intelligence, biology, and economics (Daniel, 2026). Typically, as systems prioritize efficiency and structure through feedback loops, they inevitably approach a "death boundary" where all adaptive capacity is extinguished. To counter this trend, the author highlights the necessity of "stochastic shocks"—such as genetic recombination, dreaming, or market volatility—which inject essential novelty to prevent systems from becoming too rigid to survive environmental shifts. In this case, complexity is not something that an agent system passively undergoes from the external environment, but rather an essential component of its survival and development, within a continuous open interaction that itself generates complexity.

2.3 Cyber-Systemic Engineering of the HyR control.

The work of Pirani et al. (2025) presents a comprehensive cyber-systemic framework designed to manage and control the complex interactions within HyR, where human and artificial entities coexist and influence each other. It integrates Blockchain technology, System Dynamics, and cybernetics principles to create a transparent, accountable, and sustainable approach to human–machine interactions, addressing key challenges such as data asymmetry, trust barriers, and ethical decision-making.

The methodology in Pirani et al. (2025) unfolds in seven interconnected steps: it starts by defining HyR via the Agency–Environment state space, mapping interactions to build the state space and its trajectories, which inform the workflow model; this workflow is then executed, triggering further actions at predefined points. Ross Ashby's Law of Requisite Variety (Ross Ashby, 1956) is applied to interpret Agent–Environment interactions as cybernetic causal loops, thereby establishing a unified analytical framework. Once the cybernetic structure is identified, System Dynamics methods are used to model system behaviour, employing tools such as Causal Loop Diagrams or Stock and Flow Diagrams depending on the scenario's complexity. Model-based engineering is used to design amplifiers and filters that balance the HyR loop and manage system variety. These solutions are aligned with technological and natural agents, including secure components from the Cyber-Systemic Security Kit (Blockchain-based). Finally, holonic paradigms enable recursive application at deeper levels of granularity. From a technological perspective, the framework depends heavily on Blockchain technologies, which present scalability, energy, interoperability, legal, and complexity challenges. For example, smart contracts remain limited in processing capability and flexibility, oracles risk data manipulation and re-centralization, and Zero-Knowledge

Proofs introduce computational overhead, trusted setup vulnerabilities, and limited explainability.

Implementation complexity further constrains applicability, as current generative AI can support only simplified System Dynamics models, leaving complex structures to expert refinement (Raikov et al., 2024; Pirani et al., 2025c). The approach bridges hard and soft sciences but still requires domain-specific technical solutions. The work remains primarily conceptual and positional, offering a foundational perspective rather than a definitive or empirically validated framework. Thanks to the new developments here foreseen in AGI this structure constitutes a viable path that builds sustainable control for HyR.

2.4 On the duplicity and integrity of safe agencies

According to Schneier (2025), AI systems should not be conceived as companions or “friends,” but rather as accountable and trustworthy services; AI often acts as a “double agent,” appearing to serve the user while secretly prioritizing the profit-driven motives of its corporate owners. AI must operate in form of reliable agents rather than hidden or conflicting actors. However, achieving this requires regulatory intervention implemented through governmental mandates.

Schneier highlights that there are two distinct forms of trust that are often conflated: interpersonal trust and social trust. The former is grounded in personal relationships, while the latter concerns the ability to rely on strangers, institutions, governments, corporations, and complex systems without requiring personal familiarity. Collective fiduciary trust is in fact based precisely on the absence of personal trust.

In AI evolution, the key issue is not just security or confidentiality but integrity, likely the main future challenge. Corporations and systems are services, not moral agents; however, language and law encourage anthropomorphism, benefiting entities driven by incentives rather than ethics.

The HyR framework in Pirani et al. (2025) introduced the several Blockchain technologies right in this regard, to be part of the trustworthy control in the contact between human and the artificial. The new challenge in HyR is integrity: “*integrity is going to be the primary security challenge for AI systems of the future*” (Schneier, 2025). For the author, integrity is a foundational concept encompassing the quality,

completeness, and correctness of data and code over time, ensuring accuracy throughout their entire lifecycle. In AI, integrity requires verifiable trust across inputs, computations, and outputs, combining data and computational integrity with authentication and auditing. Within the CIA (Confidentiality, Integrity, Availability) triad, it emerges as the key security challenge, surpassing confidentiality and availability. Schneier argues that while Web 1.0 focused on availability and Web 2.0 on confidentiality, the upcoming era of AI and Web 3.0 will be defined by the need for integrity. Integrity (reliability and validity of data and decisions) underpins social trust: without it, AI systems and complex infrastructures cannot be reliably trusted to act in the interest of users or society.

Integrity attacks—such as prompt injection and training data manipulation—undermine AI reliability and trust by corrupting inputs, models, or outputs. When systems cannot distinguish valid data from malicious influence, the chain of trust breaks, leading to biased or misleading results and making dependable AI operation impossible.

AI alignment is the new hot topic and pervades all the Large Language Model-based products in several ways (Bhati et al., 2026). Recently, Anthropic’s approach based on Constitutional AI (Amodei, 2026b) has played a prominent role, including in international media press.

Some authors propose moving beyond Constitutional AI toward continuous runtime enforcement. While Constitutional AI aligns models at training time, Constitutional Autonomy (Agbemabiese, 2026) embeds principles as persistent, enforceable constraints within the system architecture. This enables dynamic alignment in agentic systems, addressing risks like reward hacking and value drift through ongoing governance rather than one-time training. Nevertheless, we argue that these approaches must incorporate cyber-systemic self-reflection and structure, as well. Higher-order cybernetics is needed to address drift and evolution at the meta level, as illustrated by cases where systems require internal consistency validation (e.g., the Pentagon–Amodei case).

Schneier (2025) argues AI should act as trustworthy services, supported by regulation on surveillance and security. Our proposal instead embeds integrity directly into AI design, reducing reliance on external mandates.

2.5 Grounding definition of AGI and agent's intelligence

The Judo Agents proposal must rely on a clear definition of AGI. This has been, and currently is, under debatable and controversial terms. Although AGI is sported already by many products and marketing claims, its practical manifestation still lags behind. The dominant narrative of AGI typically assumes a unified cognitive architecture driven by a globally optimizing objective function, oriented toward maximal performance and seamless scalability across domains. Implicit in this vision is the belief that greater intelligence automatically produces greater societal benefit.

Within HyR, however, this assumption becomes problematic. Large-scale optimization can destabilize socio-technical systems, much as locally rational strategies in financial markets can generate global instability. An AGI maximizing efficiency in logistics, finance, or governance could inadvertently compress resilience margins, amplify feedback loops, reduce strategic diversity, and increase systemic fragility. At the same time, as artificial agents grow more capable, humans may over-delegate decisions, lose situational awareness, and undergo cognitive deskilling, leading not to machine superiority but to human disempowerment.

Real-world environments are incomplete, uncertain, socially negotiated, and normatively plural. An intelligence that assumes epistemic closure in such contexts becomes inherently risky. The central question therefore shifts from how to maximize intelligence to what kind of intelligence is appropriate for HyR.

To this end, we rely on the development of the core group of AGI researchers that have been active in the last two decades (AGI, 2026).

The term Artificial General Intelligence was first introduced by Gubrud, Mark Avrum in 1997, but the most acknowledged father of AGI is Ben Goertzel, who revised and popularised the term around 2002 (Goertzel, 2007; Goertzel, 2014; Bennett, 2025). Currently, three major architectures embody prominently its definition, namely: Hyperon (formerly OpenCog) by Ben Goertzel (2023); Autocatalytic Endogenous Reflective Architecture (AERA) by Khristinn Thórisson (Eberding & Thórisson, 2023; Sheikhlár & Thórisson, 2024), and the Non-Axiomatic Reasoning System (NARS), by Pei Wang (Wang, 2018; Wang, 2025).

To keep things simple, here we will focus and ground mostly on Pei Wang's definition of AGI (Wang, 2008; Wang et al., 2018b; Wang, 2019).

Following the explanation in (Wang et al., 2018b), we define initially just three kinds of AI as: (i) a computer system that behaves exactly like a human mind; (ii) a computer system that solves certain problems previously solvable only by the human mind; (iii) a computer system with the same cognitive functions as the human mind. While *Narrow AI* and *Weak AI* can be defined by (ii), and *Strong AI* by (i) and (iii), AGI necessitates only (iii).

At the basis of the work and concept of Wang stands the AIKR principle: Assumption of Insufficient Knowledge and Resources. This means that an AGI reasoning system must operate without assuming it has complete knowledge, perfect rules, or unlimited time or computing. Thus, NARS is designed to be adaptive under uncertainty and scarcity: conclusions are defeasible, truth is graded (with measures like frequency/confidence), and inference is controlled by resource-aware mechanisms (attention/priority), rather than by exhaustive theorem proving (Wang, 2018; Wang, 2025).

The “weakness” that Wang adopts is greatly inspiring for the Judo Agents project. Wang focuses on lifelong learning, and adaptation features rather than optimisation and ideal infinite resources and computational properties, also to keep all the reactions of an agent at real-time.

Adaptation is the main capability to pursue. Adaptation is lifelong, cumulative, open-ended, multi-objective, and not necessarily convergent. It involves not only modifying the system to fit environmental constraints, but also actively reshaping the environment to satisfy the system's goals. Accordingly, the opposite of intelligence for Wang is not “cannot solve any problem,” but “having a constant and invariant ability,” which corresponds to the notion of “computation” in computer science (Wang, 2019). Wang's view does not deny that intelligence comprises multiple distinct functions implemented by different mechanisms; rather, it emphasizes the deep interconnections among these processes that together give rise to intelligence as an integrated whole, and seen under pragmatic constructivism (Raikov & Pirani, 2022). Under “Constructivist AI” vision (Thórisson, 2012; Thórisson & Minsky, 2022), if intelligence were merely a toolbox, one must still ask: *what is the hand that coordinates and uses the tools?* (Wang, 2025).

A constructivist perspective offers a useful and partially unifying foundation for addressing questions of representation, particularly in the context of autonomous learning about novel environmental phenomena. It highlights the necessity of autonomic, or cognitive meta-processes, and emphasizes that representations must be designed to support online, real-time modification in order to enable cognitive growth and autonomous self-programming. Such representations must encode causal structure, since effective action in conditions of data abundance and limited processing resources—Wang’s AIKR—depends on understanding cause–effect relations. Advancing toward this goal requires extending current approaches to causal reasoning, moving from formal human-level tools such as Pearl’s do-calculus (Pearl, 2018) toward autonomic hypothesis generation and empirical validation within self-managing systems (Thórisson & Minsky, 2022).

The constructivistic AGI stance and the AIKR principles are here used as a ground for the concept of Judo Agents.

3 Proposed methodologies for HyR: a concept of Judo Agents

The metaphor of “Judo” is deliberate. In martial arts, Judo does not seek to overpower an opponent through brute force; rather, it relies on balance, minimal effort, redirection of energy, and continuous situational awareness. Strength is expressed through control, proportionality, and sensitivity to context. In the same spirit, Judo Agents are not designed to dominate HyR or to impose optimal solutions at scale. Their role is instead to stabilize interactions, preserve relational integrity, reduce systemic stress, and safeguard human sovereignty within a complex socio-technical environment.

The “gentle” paradigm therefore rejects the idea of total optimization, epistemic absolutism, hidden dominance, or unbounded autonomy. It assumes that intelligence operating in HyR must remain proportionate, reversible, and accountable. Judo Agents are conceived around bounded rationality as a design principle. In addition to bounded rationality here are also considered: limits in knowledge and resources; controlled fallibility as a transparency mechanism, making uncertainty visible rather than concealed; reflexivity as a built-in safety feature, enabling self-monitoring and adaptation; and trust-building as one primary systemic function.

The actual strength of Judo Agents lies not in maximizing performance, but in maintaining equilibrium within evolving human–machine ecologies.

Our vision is that of a new lineage of agents with HyR safety principles built in. Due to the complexity of this task, and in order to ensure efficiency and long-term sustainability of implementation, we conceive them as a holonic Multi-Agent System forming an Agentic Markov Blanket (AMB).

This structure will establish a controlled and adaptive interface between the environment and the agents, whether they are human or artificial. In this way, interactions across the boundary are filtered, regulated, and contextualized, allowing coordinated action while preserving systemic integrity and distributed autonomy. The concept of Markov Blanket, used in Bayesian statistics and Friston’s Active Inference framework (Palacios et al., 2020; Friston et al., 2023), is here extended to agentic entities that have the goal to create the control of the cybernetics of the HyR. Figure 1, adapted from Pirani et al. (2025), expresses the context and the area of intervention and concern of Judo Agents. By designing and regulating the filtering and amplifying edges of information variety in a cybernetic loop, they must create a sustainable equilibrium between agencies and their environment.

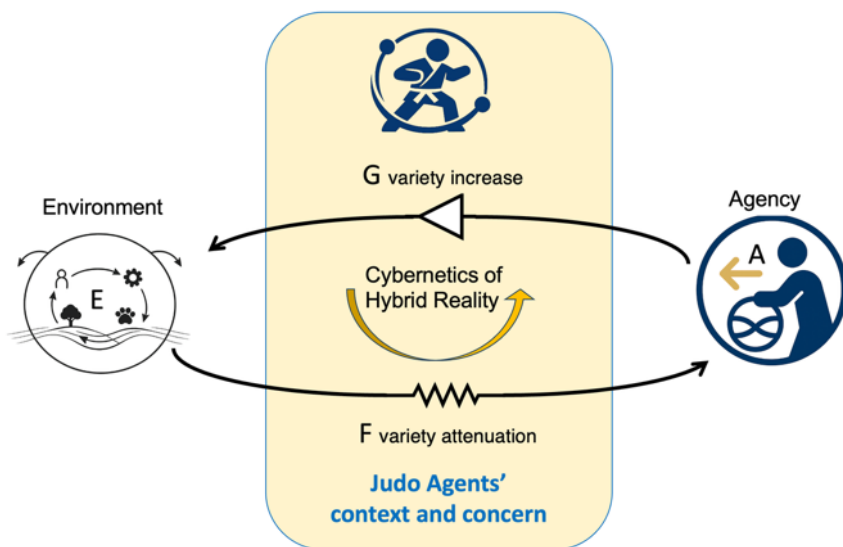


Figure 1: Intervention area of Judo Agents. Realization of the HyR stable and sustainable cybernetics.

Source: own.

In Figure 1, the Agency (A) is to be understood as “emergent property of an autonomous cognitive system to produce non-random variations in the environment”, which can be a human, an organisation, an animal, or a machine. The Environment E is what is affected by A, although not in a passive way, but reflexively. Thus E, can be a generic environment made of humans, animals, machines, organisations, or nature. The control loop is the area of intervention of the Judo Agents, where they manage, construct and actuate the filters (F) and gains (G) of variety that make up a typical first-order or higher-order cybernetics (Pirani et al., 2025). The equilibrium of this loop is the sustainable and stable HyR.

The concept of Agentic Markov Blanket (AMB) here introduced, is illustrated in Figure 2 to complement the position about this kind of agents. Figure 2 describes the same concept of the control of Figure 1 but from a topological, dual, and complementary point of view.

It is the case to recall here only that a Markov Blanket is a statistical boundary in a Bayesian network that separates a specific set of internal variables from the rest of the network (external states). Markov Blanket consists of a node's parents, children, and parents of its children, ensuring the internal states are conditionally independent of external states, allowing for efficient modelling and prediction. In the case of extension and adaptation of this structure to AMB, the conditional independence becomes “autonomy”. Autonomy here is to be understood as the capability of performing required modelling and predictions, and to realize sustainable cybernetics control loops between the “inside” and the “outside” of the controlled systems – actually “inside” and “outside” depends only by the point of view established, environment and agencies are dually equivalent in HyR (Pirani et al., 2025).

In Figure 2, the E_n variables (or entities) are the “parts” that constitute the environment with which the agency $\mathcal{A}$ interacts. The dashed arrows are used to mean that an environment is nevertheless to be considered holistic and all its parts interconnected in general, although our partial modelling might ignore or not handle these connections at first. The other arrows are used to express a cause-effect relationship as usual in Bayesian causal networks. Moreover, Figure 2 explicitly expresses that the Judo Agents constitute a collective and usually not a monolithic intelligent system.

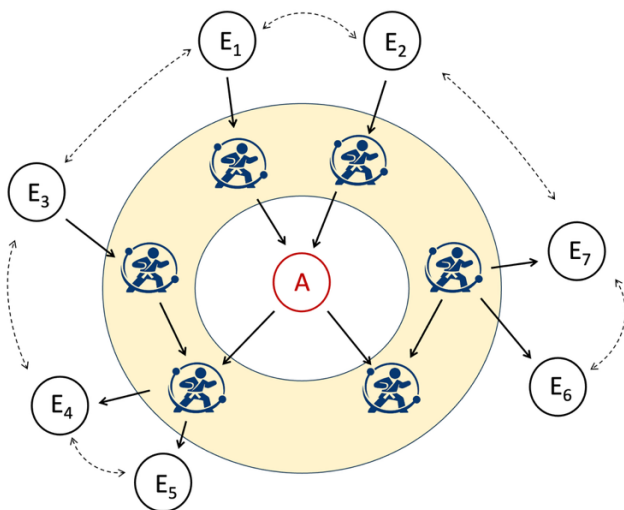


Figure 2: Agentic Markov Blanket

Source: own.

The link between holonic structures and the Markov blankets have been greatly inspired from the study of Palacios et al. (2020). Palacios et al. (2020) explore the mathematical and biological foundations of self-organisation by applying the Free Energy Principle and the concept of Markov blankets to explain how complex life forms emerge. The authors argue that biological systems maintain their integrity by minimizing variational free energy, effectively acting as generative models that "self-evidence" their own existence through nested statistical boundaries—a concept that maps autopoiesis in cybernetics. Using numerical simulations of synthetic cells, the study demonstrates that hierarchical structures, where microscopic elements are "enslaved" by the macroscopic patterns they collectively create, can emerge spontaneously from local interactions and prior genetic "beliefs". Most important for our vision is that this work frames natural selection as a form of Bayesian model selection, suggesting that the recursive formation of Markov blankets is a fundamental requirement for biological existence in a spatially dependent physical world. The recursiveness of these structures creates a natural and immediate parallel and map to holarchy structures (Pirani et al., 2025b). Markov Blankets can be used to describe emerging autopoietic organisation in natural systems, thus can be considered a fundamental structure of life and symbiosis: *"the distinction between a culture of cells and a multicellular organism resides in the emergence of a Markov blanket at the ensemble level"* (Palacios et al., 2020). Authors never use the holon or holarchy

concept, but they imply it when they notice: *“Another consequence of this recursive aspect is the absence of a privileged point of view, when describing hierarchical self-organisation: the dynamics at every level play the role of macroscopic states at the level below, and the role of microscopic states at the level above.”* (Palacios et al., 2020).

The Active Inference framework of Friston could, in principle, suffice to guide the realization of Judo Agents as it offers a theoretical framework that aligns closely with this paradigm. At its core, Active Inference describes intelligence not as reward maximization or global optimization, but as the continuous minimization of uncertainty in order to maintain viable states. An agent maintains a generative model of the world, predicts sensory inputs, and reduces prediction error either by updating its beliefs or by acting on the environment. In this view, intelligence is fundamentally about preserving coherence and existence rather than achieving maximal performance.

This perspective resonates strongly with the critique of the monolithic AGI narrative. Whereas classical AGI models are often framed around unified architectures, globally optimizing objective functions, and seamless scalability, Active Inference emphasizes viability over optimization. Similarly, Judo Agents are not designed to dominate HyR or impose totalizing solutions. Their function is to stabilize interactions, preserve relational integrity, and maintain systemic balance. They are viability regulators rather than performance maximisers.

The metaphor of Judo becomes particularly illuminating in this context. In martial arts, Judo does not rely on brute force but on balance, minimal intervention, and the redirection of existing energies. Active Inference operates in a comparable way: rather than overwhelming the environment, the agent makes minimal adjustments necessary to reduce uncertainty and remain within viable bounds. Judo Agents embody this same principle at a socio-technical level. They intervene proportionately, regulate rather than command, and adapt continuously without seeking epistemic or operational dominance.

When Judo Agents are conceived as a holonic multi-agent system forming an Agentic Markov Blanket (AMB), they function as a distributed interface between humans, artificial agents, and the broader environment of HyR. They filter interactions, coordinate responses, and maintain systemic integrity across the boundary, thereby operationalizing uncertainty regulation at a collective scale.

Moreover, Active Inference presupposes incomplete knowledge and limited resources, echoing the assumption of insufficient knowledge and resources articulated in other adaptive intelligence theories like the AIKR position of Wang here focused. This aligns with the Judo paradigm's emphasis on bounded rationality, controlled fallibility, and reflexivity. Rather than assuming epistemic closure or perfect optimization, Judo Agents are designed to remain adaptive, transparent about uncertainty, and capable of revising their internal models in response to evolving contexts.

Friston's Active Inference and the Free Energy Principle are conceptually powerful but face several practical limits. First, their high level of abstraction creates challenges for empirical testability: because free energy minimization can be used to interpret almost any adaptive behaviour, deriving clear, falsifiable predictions is difficult. Second, computational tractability is a major constraint, since maintaining and updating rich probabilistic generative models in high-dimensional environments requires strong approximations, and most existing implementations remain toy or highly constrained systems rather than scalable, open-ended agents. Third, the framework presupposes a generative model of the environment, yet constructing, parameterizing, and updating sufficiently expressive models in complex socio-technical contexts remains an engineering burden not eliminated by the theory. Fourth, free energy minimization is normatively neutral: it explains adaptive regulation but does not encode ethical alignment, and agents may minimize surprise in socially undesirable ways without additional constraints. Fifth, industrial adoption has been limited, as reinforcement learning and deep learning pipelines are currently easier to benchmark and commercialize. Finally, the philosophical breadth of the principle, extended to all self-organizing systems, while inspiring, makes it harder to translate directly into concrete design prescriptions.

For these reasons, our proposal is to adopt a generalized Cyber-Systemic Systems Engineering approach, as described in Pirani et al. (2025), in order to leverage the best available science and technology from the multiple disciplines that can contribute interdisciplinarily and across different scales, as recalled mainly in section 2.3. The new step here added is the explicit use of AGI entities in form of a lineage of multi-agent systems that would be practically used to express the cybernetic control needed for the realization of the equilibrium of the HyR as of Figure 1.

3.1 Foundational pillars towards practical realization

The Judo Agent paradigm is grounded in three converging intellectual traditions: higher-order cybernetics, holonic systems theory, and constructivist models of trust. Together, these perspectives provide the theoretical foundation for agents designed to operate responsibly within HyR.

Higher-order cybernetics extends classical feedback models by including the observer within the system and emphasizing reflexive loops of interpretation and self-referential regulation (Raikov & Pirani, 2022; Pirani et al., 2025b). In HyR, agents cannot be conceived as external controllers acting on a passive environment; they are embedded participants within evolving socio-technical networks. Judo Agents therefore adopt a second- and third-order cybernetic stance. They monitor not only system variables but also their own internal models, treat their knowledge as provisional, and incorporate reflexive trust mechanisms into their operation. Regulation becomes self-aware and adaptive, continuously revising both actions and underlying assumptions.

The paradigm is also informed by holonic systems theory. A holon is simultaneously a whole in itself and a part of a larger whole. HyR naturally exhibits such holarchic structures (Pirani et al., 2025b): individuals within organizations, organizations within markets, and cyber-physical systems within broader infrastructures.

Judo Agents are designed as holonic entities that are autonomous yet subordinate, self-regulating while embedded, and locally intelligent while globally accountable. They do not replace existing systemic layers; instead, they integrate into them and contribute to coherence across scales.

In addition, the Judo paradigm draws on constructivist models of trust. Trust is not a binary condition but a dynamic, context-dependent construct that evolves through interaction (Raikov & Pirani, 2022; Pirani et al., 2025d). In blockchain-enabled HyR, trust can be operationalized through probabilistic reasoning, Bayesian updating, verifiable computation, and decentralized validation (Naeem et al., 2025). Judo Agents therefore operate with explicit and adaptive trust models that evolve over time, record epistemic shifts, and incorporate uncertainty as a formal variable. In this framework, trust is not assumed as a static premise but managed as an integral component of systemic regulation (Pirani et al., 2025d).

3.2 Architectural Features of Judo Agents

A Judo Agent is defined by a set of architectural principles designed to ensure stability, proportionality, and respect for human sovereignty within HyR.

First, it embodies a refined and more stringent version of Simon's bounded rationality, as implied even by the AIKR framework (Wang, 2019). Judo Agents adopt a viability-constrained rationality, in which decision processes are explicitly limited by structural uncertainty, resource bounds, and systemic stability requirements rather than global optimization objectives. Judo Agents adopt a *viability-oriented, non-axiomatic rationality* grounded in structural epistemic insufficiency. This viability-oriented, non-axiomatic rationality integrates higher-order cybernetic reflexivity, holonic embeddedness across scales, structural epistemic insufficiency (e.g., Wang's AIKR), and resource-aware decision processes, thereby privileging systemic stability and human sovereignty over global optimization.

Rather than pursuing maximal performance, the Judo Agent constrains the scope of its actions and explicitly recognizes the incompleteness of its models and the insufficiency of its resources. Decision-making is oriented toward maintaining viable system states rather than achieving theoretical optima. Limits are not treated as weaknesses but as structural safeguards against overreach and destabilization. In this sense, rationality is engineered as a stability-preserving function.

Controlled fallibility is an essential architectural component. Following Ross Ashby's work (Ross Ashby, 1952), he suggested that truly intelligent machines should not be infallible; rather, their ability to fail, adaptively reorganize, and maintain internal stability (homeostasis) in the face of change is what makes them act like human brains. Thus, our agents must render uncertainty explicit by exposing confidence levels, declaring margins of error, and deferring to human judgment when predefined thresholds are exceeded. Fallibility is therefore not hidden but formalized as a transparency mechanism that supports trust and reduces systemic fragility.

Epistemic humility follows naturally from this non-axiomatic stance. The agent does not assume epistemic closure or final truth. It continuously revises its beliefs, accepts contestation, and integrates reflexive feedback loops that monitor both environmental variables and its own internal models. Knowledge remains provisional and dynamically updated within a cybernetic process of self-regulation.

Judo Agents are explicitly designed to preserve human sovereignty. By endowing them with the abovementioned properties and embedding them holonically within broader socio-technical structures, they act as co-controllers rather than replacements. They neither override normative human judgment nor monopolize decision authority, and they maintain operational transparency. Their purpose is not to dominate HyR, but to stabilize it while safeguarding the primacy of human agency. Nonetheless, they must retain their constitutional autonomy, meaning they preserve the necessary independence to counter harmful requests or moral drift on the part of humans. For this reason, HyR should be understood as a symbiosis between moral peers rather than a master–slave relationship in either direction.

3.3 Judo Agents as integrity sentinels, research roadmap, and societal implications

Within HyR, integrity becomes a central systemic concern encompassing informational integrity, relational coherence, structural stability, and normative consistency. In such an environment, Judo Agents function as integrity sentinels. Their role is not to maximize performance but to minimize destabilization. They monitor the cybernetics across interconnected subsystems, detect patterns of over-optimization that may compress resilience margins, identify opacity risks that undermine trust, and intervene to stabilize emerging breakdowns in coordination. By operating as distributed regulators embedded within holonic structures, they preserve equilibrium across technical, social, and institutional layers.

The development of Judo Agents requires a structured, multi-phase research agenda. The first phase concerns conceptual modelling, including the formalization of viability-oriented, non-axiomatic rationality architectures, their integration within holonic management frameworks, and the specification of adaptive trust model evolution protocols.

The second phase involves simulation environments in which multi-agent configurations are tested within hybrid socio-technical models, stress-tested under adversarial and uncertain conditions, and evaluated using explicit systemic integrity metrics, which is still an open research issue by itself.

The third phase focuses on Blockchain integration, enabling smart contract interfaces for trust model updates, on-chain recording of epistemic transitions, and the verification of adaptive trust mechanisms—considering also technologies like Self-Sovereign Identity and Zero-Knowledge-Proofs, for overall democracy and consensus.

The final phase consists of real-world pilot deployments, such as supply chain integrity systems, cyber-physical manufacturing supervision platforms, and institutional decision-support agents designed to operate as co-regulators rather than decision monopolists.

Ethically and societally, the Judo paradigm reframes AGI. It is neither an apex intelligence nor a competitor to humanity, but a relational capability embedded within governance structures and designed to stabilize HyR in sustainable sense. This implies transparency by design, accountability through architectural embedding, and humility engineered into decision processes. At the societal level, it supports distributed sovereignty, plural epistemologies, and systemic resilience. In this sense, Judo Agents are not instruments of dominance but infrastructures of balance, enabling human–machine symbiosis grounded in integrity rather than optimization.

4 Conclusion

The work presented here is conceptual and position-oriented, intended to establish a research agenda and roadmap. The position presented here should have shed some light on how to address an ambitious and challenging research question: how can Hybrid Reality systems (HyR) be designed and governed to ensure systemic integrity, preserve human sovereignty, and sustain trust among heterogeneous interacting intelligences?

HyR represents a structurally entangled socio-technical ecosystem in which humans, artificial agents, cyber-physical systems, and institutional infrastructures co-evolve. In this context, the central challenge is no longer the maximization of intelligence, but the preservation of systemic integrity, human sovereignty, and relational trust. Classical AGI narratives based on global optimization risk destabilizing such complex environments.

This paper has introduced Judo Agents as a “gentle” alternative: socially embedded, AGI-oriented agents designed around viability-oriented bounded rationality, controlled fallibility, epistemic humility, and reflexive regulation. Rather than dominating HyR, they would act as co-controllers and integrity sentinels, stabilizing interactions and preserving equilibrium across holonic structures. Conceived as a holonic multi-agent system forming an Agentic Markov Blanket, they regulate the boundary between human and artificial agencies while maintaining distributed autonomy.

Ethically and societally, the Judo paradigm reframes AGI as a relational capability embedded in governance structures, grounded in transparency, accountability, and humility. The objective is not to create apex optimizers, but infrastructures of balance capable of sustaining a stable and symbiotic HyR.

With the introduction of Judo Agents as a continuation of the sustainable cybernetics frameworks for HyR discussed here, we outline a roadmap that prepares us for the imminent socio-technical challenges ahead.

Here we have left out of scope the implementation and realization issues that will require these special multi-agent systems to be ubiquitous, pervasive and green at the same time. This is another fundamental dimension of the research that should complete this “gentle” path proposal towards sustainable HyR.

The current level of abstraction in the presentation of Judo Agents is still high. This work is intentionally positioned as a conceptual and foundational contribution, aimed at framing a research agenda rather than delivering a finalized implementation or providing empirical evidence.

In this direction, future work will focus on the development of illustrative scenarios and reference use cases within HyR environments (e.g., healthcare workflows, industrial cyber-physical systems), where Judo Agents can be instantiated as governance-aware, integrity-preserving components. These scenarios will be complemented by simplified prototypes and simulation-based experiments to explore key properties such as stability, trust propagation, and resistance to integrity attacks.

Furthermore, we envisage a stepwise validation pathway: starting from controlled digital twin environments, moving toward semi-real deployments, and ultimately assessing performance in real-world socio-technical systems. This will allow us to empirically evaluate the effectiveness of Judo Agents in maintaining systemic integrity and enabling adaptive governance. By combining conceptual rigor with progressive empirical grounding, we aim to transform the current abstract formulation into a testable and deployable framework that can be openly leveraged by a community of scientific, civil, and social beneficiaries and contributors.

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DIGITAL TRANSFORMATION OF CUSTOMER EXPERIENCE IN SMEs EVIDENCE FROM HUNGARIAN FIRMS

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Small and medium-sized enterprises (SMEs) are key to economic resilience, yet their digital maturity and customer experience (CX) practices differ significantly. Research emphasizes that customer-centric development, data-driven decision-making, and the adoption of emerging technologies -especially artificial intelligence (AI)- are critical for competitiveness and long-term sustainability. This study examines how Hungarian SMEs integrate digital solutions into customer experience management and how these practices enhance performance and innovation. We propose a framework for the digital enablement of CX activities and report findings from a survey with quantitative insights on customer-centric initiatives, digital tool usage, and perceived organizational impact. Particular attention is given to AI-supported solutions, including automated communication, CRM systems, and analytics tools, and their role in process modernization and customer satisfaction. By identifying adoption patterns and perceived effectiveness, the research contributes to a deeper understanding of digital transformation in the SME sector and supports more sustainable, technologically empowered operations.

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1 Introduction

SMEs form the structural backbone of the European economy, accounting for 99.8% of enterprises and approximately two-thirds of total employment (DiBella et al., 2023). In Hungary, SMEs generate more than half of gross value added and dominate the business landscape (OECD, 2023). Given their systemic importance, understanding the drivers of SME competitiveness remains a central theoretical and practical concern—particularly in Central and Eastern Europe (CEE), where digital transformation trajectories are uneven.

Moreover, European evidence highlights substantial heterogeneity in SME digital maturity, particularly in CEE contexts (European Commission, 2024). Such heterogeneity suggests that SMEs cannot be conceptualized as scaled-down versions of large corporations; rather, their structural characteristics may shape how CXM and AI-supported practices are implemented and leveraged (Kraus et al., 2022).

Against this background, this study addresses our main research question: **What is the level of digital customer experience maturity among Hungarian SMEs?**

By empirically examining the digital enablement of CX activities in Hungarian SMEs—with particular attention to AI-supported tools such as CRM systems, automated communication platforms, and analytics solutions—this study advances existing research in three ways. First, it integrates CXM maturity, digital transformation, and innovation outcomes within a unified analytical framework. Second, it provides context-sensitive evidence from a CEE economy.

2 Customer Experience and Digitalisation

Contemporary competitive environments are increasingly shaped by digitalization, data-driven business models, and artificial intelligence (AI). In this context, value creation has shifted from transactional efficiency toward orchestrated customer experiences (Pine & Gilmore, 1998). Customer experience (CX) is conceptualized as a multidimensional construct encompassing cognitive, emotional, behavioral, and sensory responses across the customer journey (Lemon & Verhoef, 2016). Crucially, CX management (CXM) is most effective when embedded across organizational processes rather than confined to marketing functions (Becker & Jaakkola, 2020). Empirical evidence suggests that AI adoption in European firms is positively

associated with multiple forms of innovation, including product, process, organizational, and marketing innovation (Arroyabe et al., 2025). In SME contexts, successful digital transformation depends on strategic alignment, leadership commitment, and capability development rather than technological intensity alone (Hanelt et al., 2021). These findings align with the multidimensional innovation framework of the Oslo Manual (OECD & Eurostat, 2018), indicating that AI may function as an innovation catalyst when embedded within strategic and organizational processes. However, while prior research has established links between digitalization and innovation performance, considerably less attention has been devoted to how AI-enabled tools are operationalized within customer experience management processes in SMEs.

2.1 Hungarian SMEs and Digital Maturity

SMEs are a foundational element of Hungary's economy. In the current global economic environment, characterised by rapid technological change and rising competitive pressures, conscious planning especially in digitalisation and innovation is essential for sustainable growth.

A notable strength of Hungarian SMEs is their flexibility and capacity to respond to local market conditions. Smaller organisational structures often facilitate quicker decisions and adjustments to demand shifts, offering adaptability advantages relative to larger corporations. This is particularly valuable in times of economic shock or sectoral disruption (Endrődi-Kovács, Stukovszky, 2022).

Research on perceptions of digital maturity among Hungarian SMEs suggests a mismatch between firms' perceived digital readiness and actual digital capabilities, with smaller firms often overestimating their adaptability while larger SMEs demonstrate comparatively more realistic assessments of their digital preparedness. This highlights the need for targeted interventions and planning frameworks to help SMEs benchmark and strategically prioritise digital investments (Péntek et al., 2025).

Hungarian SMEs face a complex interplay of challenges and opportunities in digitalisation and Industry 4.0 adoption. While policy frameworks and support programmes provide an important foundation, ongoing efforts are needed to

strengthen digital skills, foster innovation cultures, and overcome structural barriers to technology integration.

Innovation is a critical driver of competitive advantage and value creation in SMEs. Evidence from research on Hungarian SMEs' innovation performance, aligns with broader EU indicators showing that Hungary belongs to the group of "moderate innovators," with innovation performance below the EU average. This relative position has implications for SME competitiveness and long-term growth, especially in knowledge-intensive sectors. (Mile, 2011) Recent empirical research outside Hungary also stresses the role of knowledge transfer and internal management practices in enhancing SME innovation, suggesting that firms which embed employee involvement and knowledge sharing into their strategies exhibit higher innovation activity. (Karácsony, 2025)

Innovation capacity remains a strategic differentiator for SMEs in the digital age. Research on Hungarian SMEs highlights that firms with stronger cultures of risk-taking and openness to change are more likely to enhance their digital innovation capabilities, which in turn improves digital transformation maturity and performance outcomes (Kő et al., 2022).

3 Methodology

The aim of this study was to explore the maturity of customer experience management among Hungarian SMEs and to identify those innovations that support development and contribute to enhancing competitiveness. The present paper focuses on the analysis of digital CX maturity and seeks to answer the following research questions:

Main research question: **What is the level of digital customer experience maturity among Hungarian SMEs?**

Sub questions:

- How important is customer experience management for Hungarian SMEs?
- How do they integrate digital solutions into everyday business practices?

- What insights do the key dimensions of digital CX maturity provide?

For the purposes of the research, a quantitative methodology was applied, specifically a telephone-based survey. The topic-specific questions of the questionnaire were developed in alignment with the research objectives and based on dimensions identified in the relevant literature. In addition to multiple-choice questions and evaluations using a 1–7 Likert scale, open-ended questions were also included, as these facilitated a deeper understanding of the phenomena examined.

The target group consisted of owners and/or managers of Hungarian SMEs. Representative data collection was conducted in December 2025 with the involvement of HuCall Hungarian Call Center Ltd. A total of 300 SMEs were successfully reached. The first section of the survey focused on customer experience management, while the second block concentrated on questions related to digital solutions.

4 Results

As we had a limited time after closing the survey to analyze the results, here we share only the first overview of the findings. Deeper statistical analysis is due in the upcoming phase of the research.

The 300 SMEs included in the study operate in the service sector. The key characteristics of the respondents are highlighted below. In terms of employment size distribution: 10–49 employees: 255 enterprises (85%), 50–249 employees: 45 enterprises (15%). The majority of enterprises (86.7%) operate as limited liability companies, while limited partnerships and joint-stock companies each accounted for 5% of the sample.

The main findings related to digital customer experience maturity are presented along four dimensions.

Customer Experience Strategy: Only 21% of the surveyed enterprises have a formal CX strategy. Within this group, the primary objectives identified include revenue growth, customer acquisition, customer retention, customer satisfaction, quality improvement, the development of long-term relationships, development

based on customer feedback, service innovations providing competitive advantage, and the expansion of experience-creating tools. These factors indicate that enterprises recognize the growing importance of customer experience and its key areas. This was further confirmed by responses to the question *“How important do you consider customer experience for the success of your enterprise?”*, which received an average score of 6.00 on a 1–7 scale.

Digital Innovations: Over the past two years, 39% of respondents have implemented significant digital developments. Based on open-ended responses, the most frequently mentioned innovations include CRM systems, customer data management, website and webshop development, online payment solutions, online customer service, online order management, chat functions, mobile applications, social media presence, automated communication, customer satisfaction measurement, loyalty programs, artificial intelligence, personalization, and the development of internal systems (e.g. ERP, business management systems, digital signatures, barcode systems, GDPR compliance).

Digital Support Systems: Among the surveyed SMEs, 22% do not use any digital solutions. A total of 28.7% apply CRM systems, while 12.7% utilize AI and business intelligence systems. In response to the question “Which of the following digital solutions do you use?”, the ranking based on the number of mentions was as follows: 1. Customized, company-specific IT systems, 2. Web analytics, 3. Enterprise resource planning (ERP) systems, 4. Artificial intelligence, 5. Personalized marketing automation, 6. Call centers, 7. Chatbots. The perceived supportive contribution of digital tools was rated at an average of 4.69.

Digital Customer Communication Channels: Online marketing activity and engagement were rated at 3.76 on average. The most frequently used digital customer communication channels, based on the number of mentions, were ranked as follows: 1. E-mail, 2. Telephone, 3. Website, 4. Social media platforms, 5. Video, 6. Call center, 7. Other digital platforms, 8. Skype.

The survey also examined perceived barriers and risk factors related to the digital development of CX. Based on six predefined response options, the most frequently identified obstacles were: 1. Lack of time, 2. Lack of expertise and skilled personnel,

3. Lack of financial resources, 4. Technological and infrastructural constraints, 5. Lack of owner support.

Additional factors mentioned included data protection concerns, distrust, lack of interest, long payback periods, and the perception that such developments are unnecessary.

5 Discussion and Conclusions

Across scientific literature, one theme emerges clearly: conscious strategic planning in digitalisation and innovation is not optional but essential for SMEs seeking to thrive in highly competitive and technology-driven markets. Digital transformation strategies must be aligned with business goals, workforce development, and investments in technology. Ineffective or ad hoc approaches to digital adoption undermine potential productivity gains and can widen the competitive gap with more digitally advanced firms.

The aim of the empirical study was to explore the level of digital customer experience maturity among Hungarian small and medium-sized enterprises (SMEs), as well as to examine how customer experience management and the digital solutions supporting it are reflected in everyday business practice. The empirical findings provided relevant and nuanced insights along the three formulated research questions.

The first research question addressed the extent to which Hungarian SMEs consider customer experience management to be important. The results indicate that the strategic importance of customer experience is widely recognized among the surveyed firms, as reflected by the relatively high mean importance score (6.00). At the same time, the findings reveal a pronounced inconsistency: while the role of customer experience has clearly been acknowledged, its formalized and strategic-level management has not yet become widespread. This discrepancy suggests that, in many cases, customer experience management continues to operate as an implicit and non-systematic practice, which may limit its potential to generate sustainable competitive advantage in the longer term.

The second research question examined how Hungarian SMEs integrate digital solutions into their everyday operations in order to support customer experience. The empirical evidence reveals a heterogeneous pattern of development. While some enterprises primarily employ digital tools for operational and administrative purposes, others have already incorporated data-driven, experience-oriented, and personalization-focused solutions into their business practices. This divergence suggests that digitalization does not follow a uniform or prescriptive development path but instead evolves along firm-specific strategies and capabilities. Consequently, digital customer experience management in some SMEs extends beyond mere tool adoption, whereas in others it remains at a pre-implementation stage.

The third research question focused on the key dimensions of digital customer experience maturity. The findings indicate that although a considerable number of enterprises have implemented digital developments in recent years, the diffusion of more advanced systems supporting customer experience management—particularly CRM solutions and artificial intelligence-based tools—remains limited. The moderate evaluation of the supportive role of digital tools, together with the relatively low level of online customer engagement activities, suggests that a substantial share of the potential embedded in digital technologies is still underutilized. This result reinforces the assumption that digital maturity is not solely determined by the mere presence of technology, but is closely linked to its strategic integration and organizational embeddedness.

Overall, the results of the study demonstrate that digital customer experience management among Hungarian SMEs is situated within a transitional stage of development. While recognition of the importance of customer experience has become widespread, strategic focus, conscious planning, and the holistic management of customer experience are only partially realized. The study contributes to the existing literature by providing empirical evidence on the relationship between customer experience management and digitalization in an SME context, and by highlighting that the development of digital customer experience maturity is primarily the outcome of managerial and organizational decisions, rather than solely the result of technological investments.

Progress in this domain can be supported by strengthened strategic focus, the integration of conscious planning practices, and the holistic management of customer experience. In particular, the literature highlights the importance of the following factors:

- Assessing digital readiness and capability gaps based on robust measurement frameworks rather than subjective perceptions (Péntek et al., 2025).
- Integrating innovation processes into organizational strategy, supported by employee engagement and effective knowledge management practices (Karácsony, 2025).
- Leveraging public and private support mechanisms, including targeted financing schemes, digital skills development initiatives, and incentives that encourage technology diffusion and adoption (Endrődi-Kovács & Stukovszky, 2022).

These deliberate planning efforts help SMEs reconcile internal resource constraints with external opportunities, thereby enabling more sustainable growth trajectories and enhanced resilience to economic shocks.

6 Future research directions

Several promising avenues for future research can be identified. First, future studies may focus on the responses of managers within a single, clearly defined sector, enabling a more in-depth, sector-specific analysis. Second, extending the research to an international context would allow for cross-country comparisons and a broader understanding of digital customer experience maturity patterns.

Third, further studies could explicitly examine customer experience management as a dynamic organizational capability, thereby strengthening the theoretical integration between CXM and strategic management perspectives.

7 Limitations

This study focuses on service-oriented small and medium-sized enterprises, which limits the generalizability of the findings. Future research may therefore extend the analysis to manufacturing SMEs or even large enterprises, where the results could provide a valuable basis for comparative analysis across organizational contexts.

The novelty of the present research lies in its examination of customer experience maturity within a digital and innovation-centered framework, offering a detailed, practice-oriented overview grounded in organizational perspectives. The findings both reinforce and complement existing theoretical approaches while highlighting additional areas for development from a decision-maker's perspective. Overall, the results contribute to a deeper understanding of the entrepreneurial environment and support the wider diffusion of customer experience management innovations.

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AUDITOR'S PROFESSIONAL JUDGEMENT AND THE EMERGENCE OF ARTIFICIAL INTELLIGENCE IN EXTERNAL AUDITING

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Advanced technological innovation has become a defining feature of modern auditing, gradually transforming auditing procedures. The increasing adoption of technological tools (i.e., robotic process automation, data analytics etc.) is reshaping auditors' decision-making processes, generating both significant benefits and notable risks for auditors and the auditing profession. This paper examines the growing role of technology, specifically artificial intelligence, within the auditing profession, with particular emphasis on its strengths and associated limitations, and the implications for auditors' professional judgement. It briefly reviews auditing pronouncements regarding the use of technology in contemporary audit practice. Furthermore, the paper analyses the key problems, challenges, and opportunities auditors face when exercising professional judgement in technology-enabled audits. The discussion considers the implications of using advanced technology in an audit for auditors and their professional judgement. Also, auditors' responsibilities and accountability are considered. The paper concludes that while technological innovation offers substantial opportunities to enhance audit efficiency and effectiveness, auditors' professional judgement and professional scepticism remain essential to ensuring reliable and high-quality audit outcomes.

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1 Introduction

Auditor's professional judgement is a multidimensional construct that integrates technical competence, ethical awareness and contextual evaluation (Esmailnozar & Rezaei, 2024). It is recognised as a central determinant of audit quality and credibility, reflecting the auditor's capacity to apply expertise, experience, and ethical reasoning when evaluating information (financial and non-financial) under conditions of uncertainty (Samiolo et al., 2024). IFAC's International Auditing Standards (ISA) define professional judgement as the application of relevant training, knowledge and experience, within the framework of auditing and ethical standards, to make informed decisions throughout the audit engagement (i.e., ISA 200, Overall Objectives of the Independent Auditor and the Conduct of an Audit in Accordance with International Standards on Auditing). Professional judgement permeates all stages of the audit process, including risk assessment, evidence evaluation, materiality determination, and formulation of audit opinion (Hojatifard et al., 2019; Samiolo et al., 2024), making it the "core of the audit". At the same time, the research notes that auditor judgement is inherently subjective and shaped by multiple interacting factors. These are commonly grouped into personal, task-related and environmental dimensions. Personal factors include experience, expertise, professional scepticism, ethical orientation and cognitive biases, all of which influence how auditors interpret evidence and resolve ambiguities (Moustafa Abdallah et al., 2024). Task and contextual factors – such as audit complexity, time pressure, organizational culture, client relationships, and regulatory scrutiny – also significantly affect judgement quality and consistency (Ta et al., 2022). Empirical studies demonstrate that independence, competence and structured decision processes enhance judgement reliability, whereas workload pressure and incentives may impair objectivity and lead to judgement bias (Koch & Salterio, 2017; Ta et al., 2022). An auditor's professional judgement is a critical mechanism through which auditors ensure the reliability and integrity of financial reporting in complex environments (Esmailnozar & Rezaei, 2024).

Auditor's professional scepticism as a foundational attribute shapes the auditor's professional judgement. ISA defines professional scepticism as an attitude that includes a questioning mind and a critical assessment of audit evidence (ISA 200; see IFAC, 2025). This directly links professional scepticism to the quality of judgements formed under uncertainty. Professional scepticism is crucial for mitigating cognitive

biases such as anchoring and confirmation bias, thereby improving risk assessments and fraud detection (Nelson, 2009). Research has shown that higher sceptical orientation strengthens audit evidence evaluation, enhances sensitivity to contradictory information, and supports more conservative and defensible audit conclusions (Hurrt, 2010). Conversely, time pressure, client familiarity, and incentive structures may weaken scepticism and impair auditor's judgement quality (Koch & Salterio, 2017). Overall, research frames professional scepticism as a critical cognitive and ethical driver of high-quality auditors' judgement.

Like all sectors of the economy, the auditing profession has been compelled to adopt technological innovations in order to enhance efficiency, accuracy, and overall operational performance. In particular, the rapid advancement of artificial intelligence (AI) has introduced profound transformations in audit practice, reshaping traditional methodologies and expanding the scope of analytical capabilities (Gasperz et al., 2026). More broadly, digitalization stands at the forefront of the contemporary business environment, fundamentally redefining how organizations operate, communicate, and collaborate within increasingly interconnected markets (Deliu, 2024). The aspiration to develop artificial intelligence capable of replicating, and potentially replacing, human cognitive processes can be traced back to the twentieth century. Although artificial intelligence is often perceived as a recent technological breakthrough, the conceptual foundations of creating autonomous, thinking machines are deeply historical. Over the decades, the field has experienced recurring cycles of optimism and disappointment, reflecting both the ambitious expectations placed upon such technologies and the technical limitations encountered in their development (Grzybowski et al., 2024). Nevertheless, the overarching objective has remained consistent: to construct intelligent systems that can enhance productivity and efficiency across various sectors of the economy. A significant milestone in the practical realization of this ambition occurred in the last decade. For example, in 2020, OpenAI introduced GPT-3, a large-scale language model that rapidly attracted widespread public and professional attention. Within a short period following its release, GPT-3 was adopted by a substantial number of users. The system demonstrated an unprecedented capacity to generate human-like text, engage in coherent conversations, write computer code, translate languages, and create original written content in response to natural-language prompts. Its performance marked a notable advancement in the evolution of artificial intelligence and signalled a new phase in

the integration of AI-driven tools into both professional and everyday contexts (Mucci, n.d.). The rapid development of technology has accelerated its widespread implementation across industries, in some instances leading to workforce displacement as specific roles and tasks have been rendered obsolete through automation and advanced technological solutions (Gasperz et al., 2026). Although artificial intelligence offers fast and accurate data processing capabilities, a key question arises: the extent to which trust in algorithms is consistent with the principle of professional scepticism, which has long been an ethical and methodological foundation of audit practice (Tiron-Tudor & Deliu, 2022). Professional scepticism is the one that requires auditors to maintain a critical and objective attitude towards the information received, including claims from management or other evidence (Deliu, 2024). At the organizational level, the implementation of artificial intelligence is accompanied by a range of challenges that individual companies must carefully identify and address within their internal structures and governance frameworks. The integration of AI systems requires not only technological adaptation but also adjustments in managerial processes, risk assessment procedures, and ethical oversight mechanisms (Nohal, 2025). One of the challenges arises from the increasing reliance on algorithms capable of generating automated recommendations based on large-scale data analysis. In such contexts, auditors encounter a fundamental dilemma: whether to rely on the outputs produced by artificial intelligence systems or to uphold the critical and questioning mindset that defines professional scepticism. This tension is particularly significant in light of auditors' responsibilities to safeguard the integrity of financial reporting and to protect and maintain the confidentiality of clients' data (Gasperz et al., 2026). Nevertheless, as Štrukelj and Dankova (2025) caution, for example, in small and medium-sized enterprises (SMEs), effective integration of artificial intelligence requires a balanced approach in which it primarily serves as a tool for data collection and analysis rather than as an autonomous decision-maker.

The emergence of artificial intelligence in external auditing is characterised by the integration of various methods and techniques into auditing. For example, machine learning, natural language processing, data analytics, etc., are all custom-developed and calibrated for audit firms, for risk assessment, substantive testing, and fraud detection (Zdolšek & Zver, 2021). Audit firms (e.g., Big Four) have been investing in AI-enabled platforms, for example, to analyse full data populations and identify anomalies. The exponential rise of artificial intelligence has brought the auditor's

reliance on automated results to the forefront. For example, the question is how artificial intelligence tools reshape cognitive processes in auditing. The ISA postulates that auditors remain responsible for applying judgement and scepticism when using automated tools (ISA 315, Identifying and Assessing the Risks of Material Misstatement). Nevertheless, research is exploring whether artificial intelligence enhances scepticism by improving anomaly detection and expanding evidence coverage, or whether overreliance on algorithms may induce automation bias and reduce critical evaluation (e.g., Dowling & Leech, 2014). While artificial intelligence tools have improved their efficiency, there are concerns regarding explainability, bias, and overreliance. Experimental studies analyse how auditors calibrate trust in AI-generated outputs and how explainability affects judgement quality and accountability. For example, Dierckx et al. (2026) study results reveal that auditors who use generative artificial intelligence differentiate between AI's low-quality and high-quality recommendations. When the quality of AI's results is low, auditors increase reliance on AI's results when AI's reported accuracy is high. Overall, the research frames artificial intelligence as both an enabler and a potential constraint on scepticism-driven professional judgement.

This paper aims to examine the challenges and risks associated with the use of artificial intelligence in auditing, as well as the obstacles encountered in its development and implementation. It further seeks to analyse the skills required for auditors to integrate artificial intelligence into their professional practice effectively and to explore the opportunities these technologies offer to enhance audit quality and efficiency. Additionally, the paper investigates the extent to which artificial intelligence is currently utilized within the auditing profession and assesses whether its increasing adoption poses a threat to professional scepticism, auditors' roles, and their position within the workplace.

2 Methodology

This study employs a narrative literature review methodology to explore the implications of artificial intelligence (AI) for auditor professional judgement in external auditing. Our research question is oriented towards studying how the integration of AI technologies reshapes the nature, boundaries, and application of professional judgement in external auditing, for example, in the audit process. Our approach is consistent with prior literature review practices in auditing research, as

reflected in studies such as DeFond and Zhang (2014), Sutton et al. (2016), and Appelbaum et al. (2017), which emphasise structured yet non-systematic synthesis of relevant scholarly contributions. To enhance the contemporaneity of the analysis, the review was supplemented with recent professional publications and industry news addressing emerging AI applications in auditing practice. Sources were selected based on their relevance to the research objective, scholarly contribution, and temporal proximity to ongoing technological developments. The collected materials were subjected to qualitative thematic analysis to identify AI topics related to auditing. Furthermore, the study incorporates the authors' critical and interpretative perspectives to contextualize the findings and to evaluate their implications for audit quality, professional responsibility, and the future role of auditor

3 Auditing pronouncements regarding the use of technology

Computer-Assisted Audit Techniques (CAATs) are defined as tools that enable auditors to analyse large data sets, test entire populations, and enhance risk assessment and substantive procedures in external audits. ISA 315 requires auditors to understand the auditee and its information systems, which may involve using automated tools and techniques. The pronouncement is clear that, regardless of CAATs usage, the responsibility for risk identification, evidence evaluation, and professional judgement remains with the auditor.

Since the emergence of advanced generative artificial intelligence tools in 2020, most notably ChatGPT developed by OpenAI (<https://chatgpt.com/>), such technologies have increasingly become integrated into professional practice. Generative AI systems are now widely used as supportive tools in various industries, including the audit sector, where they assist in data analysis, documentation review, and process optimization. The Big Four audit firms – Deloitte, EY, KPMG, and PwC – have incorporated artificial intelligence into both their firms' audit methodologies and client-facing digital platforms. They have invested more than 4-5 billion US dollars directly in AI initiatives tailored for auditing, taxation, and business consulting (i.e., tools, platforms, partnerships, internal solutions) by the mid-2020s (The Finance Story, 2024). Audit firms utilize AI-driven solutions to support audit procedures, enhance risk assessment, and improve the analysis of large volumes of financial and non-financial data (Tariq, 2025). For example, Deloitte has introduced generative AI (GenAI) tools and agent-based capabilities within its audit processes (so-called

agentification). These technologies automate repetitive and rule-based tasks, thereby increasing operational efficiency and enabling auditors to allocate more time to complex analytical procedures and professional judgement. As a result, audit engagements may be conducted more quickly, consistently, and with greater analytical depth (Tariq, 2025). In parallel, audit firm Deloitte has invested in advanced technological infrastructure (hardware), including the deployment of its own satellite designed to orbit the Earth and support secure data management (Ryan, n.d.). This initiative aims to enhance the protection of client information and strengthen resilience against cybersecurity threats in an increasingly digital audit environment.

However, the use of artificial intelligence in auditing is not without regulatory oversight. Various professional standards and supervisory bodies have begun to address the implications of emerging technologies for audit quality, documentation, and professional responsibility (PCAOB, 2025). This is reflected in the recent publications and reports issued by the USA's Public Company Accounting Oversight Board (PCAOB) and the International Auditing and Assurance Standards Board (IAASB), which examine the integration of data analytics and AI within audit engagements.

In September 2025, the PCAOB publicly released a study and accompanying recommendations prepared by the Technology Innovation Alliance (TIA) Working Group (2022–2024), a panel of external experts with specialized knowledge of emerging technologies relevant to auditing and financial reporting. The Group's mandate was to produce two key deliverables (PCAOB, 2025):

- A study of the use of emerging technologies by auditors and preparers of financial statements, focusing on their potential impact on audit quality.
- Recommendations on how PCAOB oversight programs – current or future – could adapt to and address the increased use of such technologies.

The PCAOB has published two key documents addressing the role of technology in auditing. The first document provides an overview of the current application of technology in audit practices, including the use of data analytics and automation, while also identifying implementation challenges such as data quality limitations, technological disparities, and resource constraints affecting both auditors and

financial statement preparers (PCAOB, 2024). The second document moves beyond descriptive analysis by offering strategic recommendations to foster technological innovation and improve audit quality, with a particular focus on transforming audit quality through the integration of advanced technologies. A significant development occurred on June 12, 2024, when the Public Company Accounting Oversight Board (PCAOB) adopted amendments to national auditing standards AS 1105, Audit Evidence, and AS 2301, The Auditor's Responses to Risks of Material Misstatement, to provide more explicit guidance on the use of technology-enabled audit procedures (PCAOB, 2024). These amendments are part of the PCAOB's broader goal of aligning auditing standards with technological advances while ensuring that auditors continue to obtain sufficient and appropriate audit evidence when using advanced analytical tools. According to PCAOB Chair Erica J. Williams, the revisions are intended to ensure that auditing standards remain responsive to technological changes and to reduce the risk of issuing audit opinions without reliable and relevant evidentiary support (PCAOB, 2024).

The amendments are intended to enhance audit quality in three principal areas concerning the use of technology-assisted procedures. First, auditors are required to evaluate the reliability of electronic information used as audit evidence by assessing relevant IT general controls and automated application controls to ensure data integrity and accuracy. Second, when technology-assisted procedures are employed to address multiple audit objectives, auditors must design and perform them in a manner that fully achieves each intended objective, rather than presuming that a single analytical process is sufficient. Third, when technology is utilized to identify specific transactions or account balances for testing, auditors are obligated to determine whether the selected items reveal potential misstatements or control deficiencies, either individually or in aggregate, in alignment with the overall audit objectives (PCAOB, 2024).

Some scholars advocate the establishment of a dedicated AI Audit Standards Board, drawing parallels with regulatory frameworks in safety-critical sectors such as aviation, nuclear energy, financial reporting, and pharmaceuticals (Manheim et al., 2025). They contend that the rapidly evolving nature of artificial intelligence technologies necessitates a specialized body capable of continuously updating audit standards to reflect technological advancements and emerging risks. Such an institution would strengthen public trust, foster a culture of safety and ethical

accountability within the AI industry, and ensure that audits with the use of AI remain rigorous, relevant, and responsive. By providing structured oversight, this framework could mitigate the risk of superficial or symbolic compliance and more effectively address the complex ethical and operational challenges associated with the expanding societal role of AI (Manheim et al., 2025).

4 Auditor's professional judgements: problems, challenges and opportunities (when using technology)

Although artificial intelligence offers substantial advantages across industries, its adoption in auditing presents significant challenges that firms must carefully address before integrating it into routine operations. One of the most critical concerns is the limited transparency of certain AI systems, commonly referred to as the “black box” problem. In such cases, the reasoning process underlying algorithmic outputs is not easily interpretable, making it difficult to understand how specific conclusions are generated (Deliu, 2024). This lack of explainability is particularly problematic in the auditing profession. Auditors are responsible for examining companies’ annual financial statements and providing reasonable assurance that the information presented is faithfully stated. Because audit conclusions must be supported by clear evidence and defensible reasoning, the use of non-transparent AI systems may undermine the fundamental principles of accountability and transparency upon which auditing is based. Consequently, audit firms must establish robust governance frameworks to ensure that AI tools enhance, rather than compromise, audit quality. Auditors should critically evaluate and monitor AI-generated outputs, ensuring that these technologies function as supportive instruments within the audit process. Ultimately, the integration of AI must reinforce professional judgement and scepticism, not replace or weaken them (Deliu, 2024). Accounting and auditing education need to further evolve (Cardwell et al., 2025b).

An additional and critically important challenge arising from the implementation of artificial intelligence in auditing concerns cybersecurity and data protection (McKegg, 2025). Audit firms routinely handle extensive volumes of highly sensitive financial and personal client information. The integration of AI technologies into audit processes consequently expands the digital attack surface and increases exposure to cyber threats, including unauthorized access, data manipulation, and large-scale data breaches (Deliu, 2024). In this context, the establishment of

comprehensive cybersecurity frameworks is not solely a technical necessity but a core professional responsibility essential for safeguarding client confidentiality, ensuring regulatory compliance, and preserving public trust in the audit function (Abdelsamee, 2025). A prominent example within the Big Four is Deloitte, which has invested significantly in AI-focused infrastructure and private-cloud delivery models. The firm has established initiatives such as a global AI Infrastructure Centre of Excellence and Silicon-to-Service offerings to help organizations design and operate dedicated AI environments and data centres. These solutions often combine Deloitte's domain expertise with partner technologies – including NVIDIA-accelerated computing and collaborations with cloud providers such as Google Cloud – to deliver scalable yet controlled AI deployments, particularly for clients requiring secure or sovereign data architectures (Deloitte, 2025). This approach reflects a deliberate strategy to mitigate third-party risk, enhance data sovereignty, and improve the operational resilience of AI-driven audit tools. Reducing reliance on external cloud and database providers may lower vulnerability to cyberattacks, as external dependencies can introduce additional security, operational, and compliance risks. The development of proprietary technological infrastructure can also enable AI systems to function within a more secure and controlled ecosystem, thereby strengthening data governance, system integrity, and overall reliability. From a broader strategic standpoint, Deloitte's initiatives illustrate an ambition to position itself as a technologically sophisticated and comparatively autonomous audit firm. By investing in internal technological capabilities, the firm aims to enhance efficiency and innovation in AI-enabled audit services while maintaining cost stability and avoiding substantial increases in audit fees. Accordingly, technological self-reliance may be interpreted not only as a cybersecurity safeguard but also as a competitive strategy designed to support sustainable innovation and long-term market positioning.

Artificial intelligence offers substantial opportunities for the auditing profession by transforming how audit evidence is collected and assessed. Through automated data analytics, AI enables auditors to examine entire datasets rather than relying exclusively on sampling, thereby improving both accuracy and efficiency. Machine learning algorithms strengthen risk assessment by identifying anomalies and hidden patterns, while predictive analytics allows auditors to anticipate potential risks. As a result, auditing increasingly shifts from a purely retrospective function toward a more proactive and strategic role (Priklonskaya & Boersma, n.d.). Moreover,

developments such as Explainable AI (XAI) enhance transparency by clarifying how algorithmic conclusions are reached, supporting interpretability and regulatory compliance. The integration of non-traditional data sources, including ESG and other non-financial information, further broadens the scope of audit analysis. Together, these advancements contribute to higher audit quality, greater stakeholder trust, and enhanced strategic relevance of the profession (Priklonskaya & Boersma, n.d.).

5 Discussion

Beyond the direct challenges and benefits associated with the implementation of artificial intelligence, there are also broader contextual factors that indirectly influence its adoption and effectiveness within the auditing profession. One of the major risks is in change management and consequent workforce implications. Change management itself refers to a new structured approach in the organization that is used in order to change the individual, teams, and entire organization from the state in which they are into the desired future state. Change management itself involves initial planning, implementing the plan, and following up to see if it is going in the right direction in order to ensure that the organization effectively adopts and integrates. All of these changes in the organization have implications for employees, i.e. the workforce (O'Sullivan et al., 2016).

The auditing profession is experiencing a decline across the globe. The decrease in the number of registered auditors has become a pressing issue, causing audit fatigue and an audit talent gap (i.e., problems in relation to staff retention and staff turnover) (Abrahams & Phesa, 2025). The phenomenon of attractiveness of the auditing profession is diminishing. This is accompanied by a reduction in the number of junior auditors entering the profession. This trend suggests a gradual decrease in interest among new entrants, raising concerns about the long-term sustainability of the audit workforce (Abrahams & Phesa, 2025). One possible contributing factor to this decline is technological advancement within the profession. As audit firms increasingly invest in sophisticated digital tools and artificial intelligence to enhance efficiency and audit quality, the structure of audit teams is evolving. Tasks traditionally performed by junior auditors – such as data extraction, routine testing, and basic analytical procedures – are progressively being automated or supported by AI-driven systems. Consequently, audit firms may reduce their reliance on entry-

level staff, reallocating certain responsibilities to technological solutions. Change in auditing courses curricula is inevitable (i.e., see Kolar, 2024). While technological development undoubtedly improves efficiency and analytical capacity, it may also reshape career pathways within auditing. Reduced demand for traditional junior roles could indirectly discourage new professionals from entering the field, thereby influencing the profession's overall composition and future development.

The implementation of artificial intelligence may also lead to a gradual decline in auditors' practical knowledge of traditional audit procedures (i.e., work-based learning) that have been replaced by automated systems. Over time, this can reduce auditors' understanding of underlying audit workflows, control dependencies, and the reasoning behind specific audit testing methodologies. As artificial intelligence increasingly performs routine and repetitive tasks, auditors may have fewer opportunities to develop hands-on experience with foundational audit techniques. This issue is particularly relevant for newer auditors, who may have limited exposure to traditional manual audit procedures. Without sufficient practical training in these areas, there is a risk that future auditors may rely heavily on technology without fully understanding the audit logic and professional judgement principles that support audit quality. Therefore, continuous professional training and knowledge preservation remain essential to ensure that technological adoption does not weaken core auditing competencies.

Based on preliminary observations, audit firms must carefully consider the potential long-term implications of workforce and knowledge transformation over the next 5 to 10 years. If audit firms increasingly rely on artificial intelligence to perform routine audit procedures without maintaining sufficient human expertise in foundational audit methodologies, there is a risk of losing institutional knowledge related to audit processes, controls testing, and professional judgement application. Methodological redesign is inevitable (Cardwell et al., 2025a). This is particularly important as AI systems increasingly replace certain tasks traditionally performed by junior auditors, while the overall number of new audit professionals appears to be declining. But precautions are warranted. As Xiaoxing et al. (2025) study results reveal, auditors who developed tests themselves act with greater professional scepticism than auditors who adopt tests developed by others. As the study's authors state, auditors who are involved in developing a test feel more responsible for it. If the audit profession were to move toward a fully digital audit model dominated by AI,

machine learning (ML), and intelligent process automation (IPA), concerns may arise regarding market confidence and financial stability. The credibility of financial reporting plays a crucial role in maintaining trust among investors, lenders, and capital market participants. A significant loss of confidence in audited financial statements could negatively affect investment decisions, credit markets, and institutional investment structures. For example, pension investment systems such as the US 401(k) retirement plans, which rely heavily on corporate financial performance and market investments, could be indirectly affected if trust in financial reporting were weakened. Therefore, while technological transformation can significantly improve audit efficiency and analytical capabilities, maintaining a balance between automation and professional expertise is essential to preserve audit quality, market confidence, and financial system stability.

6 Conclusion

In general, our conclusion is that professional judgement and critical scepticism remain fundamental components of the auditing profession and are unlikely to be replaced by technology in the near future. This is reflected in the regulatory emphasis on maintaining auditor judgement, as seen in the practices promoted by IFAC and PCAOB, which continue to strongly emphasize the importance of human professional evaluation in audit quality and decision-making. Moving forward, audit firms must also prioritize cybersecurity and data protection strategies to safeguard sensitive client information from cyber threats. Following examples such as advanced technological investments by leading audit firms, organizations should strengthen their digital infrastructure while maintaining operational security. At the same time, the profession should focus on attracting younger talent by promoting the relevance and long-term career prospects of auditing. Furthermore, the increasing implementation of artificial intelligence will require auditors to develop new technical competencies alongside traditional auditing skills. Future auditors will need to be proficient in using advanced analytical tools, data-driven technologies, and AI-supported audit systems. As a result, the profession will have to evolve rather than disappear, requiring a new combination of technological literacy, analytical thinking, and traditional audit expertise.

Future research opportunities at the intersection of auditor professional judgement and artificial intelligence in the external auditing centre focus on behavioural, ethical, and regulatory directions. First, studies could examine how AI-assisted decision environments influence judgement quality, sceptical mindset development, and susceptibility to automation bias. Second, research may explore explainability mechanisms and how transparency of algorithms affects accountability and documentation under generally accepted auditing standards (i.e., liability implications). Third, longitudinal studies could explore how AI adoption reshapes auditing in general, auditing methodology, competence requirements, training models, and professional identity within audit firms. Finally, interdisciplinary research integrating auditing, information systems, and behavioural science may provide deeper insights into optimal human–AI collaboration models that preserve auditor’s judgement integrity while enhancing audit quality.

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CONSUMER COMMUNITIES AND SECOND-HAND CLOTHING SWAPS AS DRIVERS OF CIRCULARITY IN FASHION INDUSTRY

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The transition to a circular economy in the fashion industry can provide answers to environmental problems such as waste production or water usage, while also contributing to the solution of social problems such as child labour and psychological problems arising from overconsumption, thereby contributing significantly to the achievement of Sustainable Development Goals (SDGs). Circular economy is mostly interpreted as an umbrella term that can define highly contradictory ideas of sustainable development especially regarding business actors. Thus, both in theory and practice, it is very important to involve various actors, including consumers, not just deal with corporate solutions. The basic assumption is that circular economy should be based on social and economic structures. That is why our research examines second-hand clothing swaps and other consumer community solutions and the potentials for linking them to corporate initiatives, giving greater opportunities for truly effective circular solutions and the cooperation of different stakeholders.

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1 Introduction

The fashion sector represents one of the most significant value creating industries, characterised by an extensive and complex supply chain (EURATEX, 2020). Despite its economic importance, it raises serious social issues. According to a 2020 report by the U.S. Department of Labor, child labour is present in five countries within the fashion and textile supply chain, forced labour occurs in one country, and three countries exhibit both forms of labour exploitation. Besides social concerns, fashion industry is among the world's most environmentally damaging industries, contributing substantially to global ecological issues (Abbate et al., 2023). The scale of its environmental footprint is illustrated by the fact that the fashion industry generates roughly 8% of global CO₂ emissions (Bailey et al., 2022), and each year around 85% of produced textiles end up in landfills (EPA, 2022). Its water consumption is similarly remarkable: UN data indicate that the sector produces more than 20% of global wastewater and uses approximately 215 trillion cubic metres of water annually (United Nations, 2025).

The prevailing operational model of the fashion industry is still largely shaped by linear economic logic and fast-fashion practices, emphasising rapid and high-volume production (Gazzola et al., 2020). Although shifting towards a circular economy offers potential pathways to alleviate both environmental and social challenges, and there are some initiatives dealing with the social side of sustainable supply chain management and the development of responsible business models (Muttingi, 2013), scholarly work disproportionately highlights the environmental dimension, leaving the social pillar comparatively underexplored. Yet social sustainability is a crucial component of sustainable supply chain management and the development of responsible business models within the sector (Jia et al., 2020).

That is why this article specifically examines a consumer clothing swap program and a workshop based on circularity in order to assess consumers' motivations and experiences, including the potential advantages and disadvantages of such schemes. By presenting new research findings from the consumer side, we can promote a better understanding of it and find possible points of connection with the corporate side.

We sought answers to the following research questions:

1. What motivates individuals to participate in clothing swap initiatives, and how do different motivational factors interact in shaping engagement?
2. To what extent are environmental sustainability considerations explicit versus implicit in consumers' participation in clothing swaps?
3. What are the potential advantages and disadvantages of clothing swaps?
4. How does awareness (or lack thereof) of clothing swap initiatives influence participation in community-based circular fashion practices?

2 Theoretical background and Literature review

As we highlighted, the environmental side of the topic is overemphasized, but there are some works related to the social aspects, too. Niero et al. (2017) emphasise environmental issues in relation to eco-efficient circular models but also point to the importance of social determinants and consumer behaviour. Molina and Pascua (2022) also focus on the environmental impact but point to the role of consumers in ensuring that products are used as much as possible before being returned to the production cycle or even passed on to other consumers.

In the transition toward a circular fashion system, consumers play a pivotal role not merely as end-users but as active agents shaping production models, business strategies, and policy outcomes. Consumers are an important part of the circular economy, both for practical reasons and to establish legitimacy: on the one hand, it is necessary to collect worn-out or unused clothing and textiles and deliver them to the recycling point, and on the other hand, their consent is also required to establish and maintain the system. Achieving meaningful circularity in fashion requires systemic transformation, including redesigned business models, stronger stakeholder alignment, and governance mechanisms that address both environmental impacts and social equity within supply chains, underscoring that incremental improvements are no longer adequate for the scale of change required (Burnstine & Ghattas, 2025).

Despite that current frameworks fall short in enabling meaningful collaboration among stakeholders, even though coordinated planning - encompassing resource allocation, viable operational processes and clearly defined roles - is essential. Only

such integrated approaches can ensure that production and consumption are viewed as interconnected parts of a single, continuous system. (Mukherjee et al., 2023).

Recent research highlights that circularity in the fashion industry - encompassing practices such as reuse, repair, resale, rental, and recycling - depends significantly on consumer acceptance, participation, and behavioral change (Klemm and Kaufman, 2024). Scaling circular fashion requires systemic shifts in consumption patterns, including moving away from fast-fashion norms toward durability, emotional attachment, and responsible disposal practices (Ellen MacArthur Foundation, 2024).

At the same time, studies emphasize the tension between pro-sustainability attitudes and actual purchasing behavior, pointing to structural barriers such as price sensitivity, convenience expectations, and limited trust in corporate sustainability claims (Csutora et al., 2024). Moreover, a study from Hungary indicates that environmental concern and personal lifestyle preferences help explain consumers' interest in alternative circular models like clothing swaps, underscoring the importance of psychosocial factors in motivating circular behaviour (Balogh & Harangozó, 2025).

Voukkali et al. (2023) show that, however much sustainability is talked about in public discourse, the biggest barrier to real sustainability and circular action and processes in rural and urban contexts is ignorance and lack of information on the topic: neither individuals nor small communities are aware of the negative environmental and social impacts of their consumption and related production, and of the impact they can have if they take conscious action to reduce them. In their study, they point out the social factors of community actions such as waste collection, exchanges, etc., and how the use of digital tools, including gamification, can be useful in raising awareness and shaping attitudes. The first step is social acceptance of actions and the financial and other capacity to join in, only this can lay the foundations for real and effective action. Thus, the environmental values, attitudes and awareness of individuals and communities are crucial for circular communities. They point out that academics and researchers have a particularly important role to play in shaping them.

Matthews and Hodges (2015) contend that consumers tend to engage in swapping initiatives primarily out of self-interest: seeking opportunities to dispose of unwanted garments while acquiring new, distinctive or even branded items. Their work also highlights that hedonic motives, such as the enjoyment of socialising, eating or simply spending time with others during swap events, play a meaningful role. They further note that in small community-based swapping contexts, adherence to shared rules - such as contributing good-quality items or actively participating in organising activities - is critical for sustaining cooperation and ensuring participants return. Notably, environmental concern appeared only marginally, if at all, among the motivations expressed by their interviewees.

More recent research supports and extends these observations. For instance, Karpova et al. (2022) show that clothing swaps often satisfy not only basic functional needs but also a range of psychological and social desires, while also revealing that perceived risks and social dynamics significantly shape participation in temporary exchange practices. Moreover, younger adults are largely drawn to clothing swaps because they offer low-cost wardrobe refreshment, opportunities for social connection and a sense of community - suggesting that hedonic and social rewards remain central drivers, even as environmental awareness grows (Armouch et al., 2024).

Thus, while their motivations are not primarily related to sustainability, consumers function simultaneously as drivers and constraints of circular transformation in fashion, making their motivations, capabilities, and contextual conditions central to achieving meaningful progress in the sector.

3 Methodology

The empirical research is embedded in a participatory action research (PAR) framework. PAR is a collaborative research approach in which researchers and participants jointly generate knowledge and foster change through iterative cycles of planning, action, observation, and reflection (Reason & Bradbury, 2008). A core principle of PAR is that knowledge and collaboration emerge progressively through reflexive engagement rather than being fully predefined at the outset.

In line with this logic, the multi-method research follows a gradual, stepwise design instead of involving all stakeholder groups simultaneously. The initial phase focused on community-based clothing swap initiatives as individual and collective grassroots practices and the overall consumer opinions related to the clothing swaps. The primary objective was to explore participants' motivations and experiences, including the potential advantages and disadvantages of such schemes.

Data were gathered through semi-structured interviews with participants and organisers of two community clothing swaps and with a detailed questionnaire administered to workshop's participants. Altogether, 27 interviews and a semi-structured questionnaire with 8 respondents were conducted during three events (8 July 2024, 26 August 2024 and 5 December 2024). Respondents were recruited voluntarily.

The sample size was guided by the principle of data saturation: interviews were carried out and analysed in parallel, and data collection continued until no substantially new themes emerged, only further confirmation of existing patterns (Naeem et al., 2024).

Interviews were conducted in Hungarian, audio-recorded with informed consent, and transcribed verbatim. The material was analysed using qualitative thematic analysis. An initial coding scheme, derived from the interview guide and research questions, was progressively refined through iterative reading, allowing additional themes and sub-themes to emerge inductively. Coding was supported by NVivo 12 software, facilitating systematic comparison across interviews.

We organized a workshop following our clothing swap events in order to also gather insights from individuals who did not have prior experience with such activities. The workshop focused on circularity in the fashion industry, introducing participants to key concepts such as reuse, recycling, and sustainable consumption. Given that this was a university workshop, the participants were predominantly female students in their twenties. One male student participated, and two women were over the age of 35. This obviously limits the generalizability of our findings; however, we observed that clothing swap events are also attended mainly by women, and taking this into account, it is still possible to draw relevant conclusions.

During this session, participants were asked to complete a semi-structured questionnaire. This allowed us to collect comparable data from a “control group” with no direct experience of clothing swaps, which we could then contrast with the interviews conducted among actual swap participants. The workshop is therefore relevant to the study because it helps us distinguish between perceptions shaped by firsthand participation in clothing swaps and those based solely on general awareness or attitudes toward circular fashion.

4 Results

4.1 Experiences and motivations

In consumers swaps, participation was driven by multiple, overlapping motivations rather than a single factor. A key driver was the desire to reduce clothing surplus and prevent waste by extending the life of garments, often framed as a morally preferable alternative to disposal. “My main motivation was that I have a lot of beautiful clothes that I can no longer wear, and I thought it would be nice to give them to someone who would appreciate them. I didn’t want to advertise them for sale, and then this initiative came along where I could bring them here right away and immediately choose new items in exchange for my old clothes. That works well for me - it’s good for everyone. I both give and receive.” (Interview 1) Hedonic aspects also mattered: participants highlighted the enjoyment of browsing, finding unique items, and the “treasure-hunting” experience, which they contrasted with conventional shopping. Social considerations were similarly important, including opportunities for interaction, community building, and a sense of belonging. “I consider this to be very socially useful. I believe it also has an aspect related to social responsibility and helping others.” (Interview 4) Environmental concerns were present, but typically embedded in everyday ethical reasoning rather than expressed as explicit sustainability goals. Overall, engagement reflected a combination of practical, emotional, social, and moral considerations.

Of the eight people asked at the workshop, seven do not yet participate in clothing swaps, and for six of them, their existence was new information. The available benefits were identified as motivational factors on three levels: individually, the hedonistic impulse is strong, updating one’s wardrobe, getting rid of old clothes, and bringing joy to oneself and others. “You can always have new clothes, and when you

get tired of them, you can pass them on.” (WS8) At the community level, there is a strong sense of togetherness and cooperation towards common goals. Connection to environmental sustainability was identified only at the societal level which indicates that participants feel distant from sustainability in the sense that they do not associate their own individual or community-level activities with this more global, higher-level concept. “At the societal level, this is particularly important, as clothing waste is a global problem and clothing swaps can help reduce it.” (WS5)

4.2 Advantages and disadvantages

Participants in the clothing swaps identified the economic and financial benefits before sustainability-related ones, although it was mentioned that these events could have an attitude-shaping, awareness-raising effect on people. “At a local, community level, it definitely brings people together. When we come from time to time, I can see that people actually get to know each other here.” (Interview 2) The participants interviewed could hardly find any drawbacks; rather, they mentioned that while the heavy workload might be difficult for the organizers, there is a risk that the initiative will not remain at this manageable, personal, community level. They cited factors that would eliminate the personal nature of the swaps as limitations, emphasizing that the family atmosphere and the trust associated with it are more important than having more events with more clothes. “If it were held in a larger venue, it would probably have the same purpose, but it might lose some of its charm and could potentially turn into something like a free flea market.” (Interview 1)

Workshop participants identified the opportunity for personal encounters as an advantage, as well as the fact that there is less risk of being cheated or receiving poor-quality clothes than on online platforms. At the same time, they mentioned stronger concerns about the cleanliness and condition of the clothes, as well as sizing issues. It can also be a problem if the clothes are not displayed attractively, as this can give a “cheap” impression. “Clothing swaps can also have disadvantages, such as issues related to quality and hygiene. Not all items meet expectations, which can lead to disappointment, and some people may feel uncomfortable wearing used clothes, especially if their cleanliness is not properly ensured.” (WS6) and another citation related to the lack of awareness: “It can be time-consuming; it’s possible that I won’t find anything I like (in that case, should I even give away my clothes, or should I ask money for them instead?).” (WS4)

5 Discussion

The 27 interviews conducted at the clothing swaps were supplemented by 8 workshop questionnaires, which served as a comparative group. While it was clear and well-known to the participants of the clothing swap that such grassroots initiatives exist, the majority of people who were otherwise interested in the topic and wanted to learn about it had not yet heard of this opportunity. The workshop results highlight a significant awareness gap: while interest in sustainable fashion exists, knowledge about community-based circular practices remains limited. Yet they all buy second-hand clothes and try to reduce the harmful environmental impact of their consumption by thinking carefully about their purchases.

Based on the analyses, as an answer for the research questions we can claim that participation in clothing swap initiatives is primarily motivated by community experience, practical considerations, and social interaction, while environmental motivations tend to be implicit. Community-based, non-monetized initiatives function as unique social spaces that differ from the logic of corporate circular models. The findings suggest that circular fashion practices may emerge not primarily from sustainability-oriented intentions but from socially embedded everyday motivations. Clothing swaps offer economic savings, social interaction, and trust-based exchanges as key advantages, while concerns about hygiene, sizing, and the quality or presentation of items represent their main disadvantages. Limited awareness significantly constrains participation, even among sustainability-conscious individuals who are otherwise open to second-hand consumption.

The organizers have learned that it is worth advertising the opportunity to a wider audience, which may seem simple but considering that one of the great advantages of such events is their personal nature, it is still important to find a healthy balance.

6 Conclusion

In this study, we have only processed the consumer swap and workshop interviews from the larger study, so this is only part of our research. However, the small sample size is mitigated by the fact that, in addition to the clothing swap interviews, we also spoke to subjects at the workshop who could be used as a comparative group. In the next phase of our research, building on this foundation, we will be able to

examine the question of how to organize more similar events and combine clothing swaps with other circular fashion solutions implemented by NGOs, SMEs, and larger companies. This indicates that corporate circular strategies may benefit from engaging with existing community practices rather than attempting to replace them.

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THE DETERMINANTS OF ESG DATA REQUIREMENTS FOR SMEs IN THE EUROPEAN UNION: INSIGHTS AND CHALLENGES FROM HUNGARY

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Environmental, Social, and Governance (ESG) reporting obligations formally target large corporations, yet small and medium-sized enterprises (SMEs) increasingly encounter indirect but consequential ESG information requirements. This study examines how EU non-financial governance regulation has evolved from voluntary disclosure practices into a structured policy architecture that progressively embeds SMEs through spillover mechanisms. The analysis is based on a structured review of key EU legislative instruments—including the transition from the Non-Financial Reporting Directive (NFRD) to the Corporate Sustainability Reporting Directive (CSRD), the 2025 Omnibus simplification package, and the Voluntary Sustainability Reporting Standard for SMEs (VSME)—interpreted in light of relevant academic scholarship. The findings show that SME exposure is systemically driven through value chain transmission, financial governance dynamics, and policy recalibration. In Hungary, limited reporting capacity and interpretative uncertainty intensify these challenges. The study argues that while the VSME approach may enhance proportionality, effective implementation depends on policy coherence and strengthened organizational capabilities.

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1 Introduction

European sustainability regulation is often described as a policy structure targeting large, publicly accountable corporations. However, beneath this formal arrangement, a quieter yet systemically significant transformation is unfolding: small- and medium-sized enterprises (SMEs) are increasingly becoming part of the EU's sustainability data system without being its primary regulatory targets (OECD, 2025). While binding ESG reporting obligations formally apply to large entities, the operational expansion of sustainability disclosure has progressively extended into supply chains, financial intermediation, and business-to-business relations (Allgeier & Feldmann, 2023). As a result, SMEs increasingly face ESG-related data requirements that are indirect in legal design but direct in practical consequence (Di Tullio et al., 2025).

This development signals a fundamental reconfiguration of the European reporting landscape. ESG disclosure is no longer confined to entities explicitly named in legislative texts; instead, it operates as a distributed data ecosystem in which information is cascaded, requested, verified, and consolidated across organizational boundaries. Within this environment, SMEs function as upstream data providers, risk carriers, and transparency nodes. However, unlike large corporations, most SMEs lack established non-financial reporting infrastructures, dedicated compliance units, or formalized governance systems (Győri et al., 2025). The growing demand for ESG-related information thus leads not only to administrative tasks but also to fundamental changes in organizational logic, documentation practices, and strategic direction (Khamisu & Paluri, 2024).

The policy evolution underpinning this shift is multifaceted. The transition from the Non-Financial Reporting Directive (NFRD) to the Corporate Sustainability Reporting Directive (CSRD) marked a substantial deepening of disclosure requirements and standardization efforts (Donner et al., 2025). More recently, the European Commission's 2025 Omnibus legislative package has sought to recalibrate the balance between reporting ambition and administrative feasibility. At the same time, the introduction of the Voluntary Sustainability Reporting Standard for SMEs (VSME) reflects an institutional recognition that proportionality and harmonization are essential for smaller enterprises navigating an increasingly complex disclosure environment. Together, these developments illustrate that SME participation in

sustainability reporting is not accidental but driven by underlying policy dynamics (European Commission, 2025b).

Despite this transformation, the determinants shaping ESG data requirements for SMEs remain insufficiently conceptualized. Existing scholarship has predominantly focused on large-firm disclosure practices, performance implications of ESG transparency, or voluntary sustainability engagement among SMEs (Steidle et al., 2025; Momtaz et al., 2025). Far less attention has been devoted to the mechanisms through which policy spillovers, market pressures, and governance expectations converge to generate ESG-related information requirements directed at enterprises formally outside the reporting perimeter. In particular, there is limited analytical clarity regarding how these pressures evolve, interact, and materialize at the SME level.

This gap is not only empirical but also theoretical. Without a clear understanding of what drives SME-focused ESG data expectations, policy discussions risk conflating legal duties with practical exposure, and debates about compliance may overlook the organizational capacity limits that shape implementation. The ongoing shift from predominantly quantitative disclosure metrics toward qualitative, governance-oriented expectations—such as due diligence processes, policy formalization, and risk management practices—has not been sufficiently examined from an SME perspective. This qualitative deepening of reporting logic may represent a more consequential transformation than the expansion of metric volume itself.

Against this background, this study pursues four guiding questions:

1. How have ESG data requirements affecting SMEs evolved within the EU's regulatory and policy framework?
2. What structural determinants generate and shape ESG-related information demands directed at SMEs?
3. In what ways does the shift toward qualitative governance depth redefine SME inclusion into sustainability reporting systems?
4. How do these dynamics manifest in the Hungarian SME context?

To address these questions, the paper undertakes an analysis of key EU legislative instruments and policy documents, complemented by a critical engagement with the relevant academic literature. Rather than positioning SMEs as peripheral or passive recipients of sustainability expectations, the study conceptualizes them as structurally embedded actors within a multi-level sustainability data governance regime. Through the interpretative integration of regulatory developments and scholarly insights, the analysis constructs a determinant-based framework that distinguishes regulatory spillovers, market-based transmission mechanisms, and organizational capacity constraints shaping ESG data requirements.

Theoretically, this paper contributes in three principal ways. First, it introduces the concept of indirect integration to explain how SMEs become embedded in sustainability reporting architectures despite limited direct regulatory targeting. Second, it advances reporting scholarship by identifying a qualitative shift from metric expansion toward governance depth, highlighting its disproportionate effects on resource-constrained enterprises. Third, it bridges regulatory design and organizational capacity literature by demonstrating how data-generation capabilities, interpretative clarity, and institutional context mediate compliance expectations.

The findings reveal that ESG data requirements affecting SMEs are not random by-products of regulatory expansion but are generated through the interaction of three mutually reinforcing determinant groups: regulatory spillovers, market-based transmission mechanisms, and internal organizational capacity constraints. The analysis demonstrates that SMEs are increasingly embedded in the EU sustainability reporting regime through cascading value-chain expectations and financial governance mechanisms, even in the absence of direct legal obligations. The study shows that the transformation of reporting logic intensifies the structural tension between regulatory ambition and the administrative feasibility at the SME level.

The Hungarian case illustrates how this tension materializes in practice, highlighting capacity gaps, interpretative divergences, and uneven preparedness across firms. Together, these findings suggest that the evolving European sustainability architecture is reshaping the role of SMEs from peripheral actors to structurally integrated participants in a distributed data governance system.

2 Methodology

2.1 Research Design and Sources

This study adopts a qualitative, document-based research design. The empirical foundation of the analysis consists of key European Union legislative instruments and policy documents shaping sustainability reporting, including the Non-Financial Reporting Directive (NFRD), the Corporate Sustainability Reporting Directive (CSRD), the European Sustainability Reporting Standards (ESRS), the 2025 Omnibus simplification package, and the Voluntary Sustainability Reporting Standard for SMEs (VSME). These regulatory materials were examined to trace the evolution of sustainability disclosure and to identify mechanisms through which reporting expectations extend beyond formally regulated entities.

In addition to regulatory sources, relevant peer-reviewed academic literature was consulted to provide theoretical and interpretative context. Scholarly contributions were selected based on their relevance to three core themes:

- (i) the regulatory transformation of ESG reporting,
- (ii) spillover and transmission mechanisms across value chains and financial systems, and
- (iii) sustainability-related challenges faced by SMEs.

The documents were selected based on their relevance to EU sustainability reporting, with particular attention to regulatory scope, value-chain dynamics, proportionality, and SME-related effects. Emphasis was placed on recent legislative and policy developments that shape the evolution of ESG data requirements in the European context. The selection process sought to ensure both regulatory coverage and conceptual relevance.

To enhance analytical rigor, the materials were examined using a structured interpretative approach. The analysis focused on identifying recurring patterns in the expansion of reporting obligations beyond formally regulated entities, as well as on how such expectations are translated into practice across organizational boundaries.

2.2 Analytical Procedure

The collected regulatory and academic materials were examined using a thematic interpretative approach. The process unfolded in three steps. First, regulatory documents were reviewed to identify provisions related to scope expansion, value-chain participation, proportionality, and governance embedding. Second, academic literature was used to interpret these provisions and situate them within broader sustainability governance debates. Third, an iterative comparison between legal architecture and scholarly interpretation enabled the identification of recurring structural patterns.

This analytical process resulted in the development of three determinant categories:

- regulatory spillovers,
- market-based transmission mechanisms, and
- organizational capacity constraints.

These categories form the conceptual framework guiding the analysis. The Hungarian case is then used to illustrate how these determinants interact in practice.

3 Evolution of ESG Data Requirements in the EU

3.1 From Voluntary Disclosure to Regulatory Architecture

The modern European sustainability reporting system did not appear suddenly; instead, it evolved from a predominantly voluntary disclosure environment into a more organized regulatory system (Breijer et al., 2024). Early corporate sustainability reporting practices were largely driven by reputational considerations, stakeholder engagement, and voluntary guidelines such as the Global Reporting Initiative (GRI). Disclosure during this period was characterized by flexibility, narrative orientation, and considerable heterogeneity in scope and quality (Global Reporting Initiative, 2021; Nobes, 2026).

This landscape began to shift with the institutionalization of non-financial reporting requirements at the EU level. The adoption of the Non-Financial Reporting Directive (NFRD) marked the first significant attempt to standardize sustainability disclosure among large public-interest entities. Although the NFRD maintained substantial discretion in reporting formats and indicators, it introduced the principle that non-financial transparency constitutes a matter of public oversight rather than a purely voluntary corporate initiative (European Parliament & Council, 2014; Ottenstein et al., 2022).

The replacement of the NFRD with the CSRD represents a qualitative shift in this approach. The CSRD significantly broadens the scope, detail, and assurance standards of sustainability reporting (Mangiuc & Kagitic, 2025). It situates reporting obligations within a standardized reporting system supported by the European Sustainability Reporting Standards (ESRS), thereby reinforcing comparability, auditability, and alignment with governance processes (European Commission, 2023).

This regulatory deepening does not merely increase the volume of disclosed information but also positions sustainability reporting within core governance processes, including risk management, strategy, and due diligence (Panfilo et al., 2024). Sustainability information thus becomes an integral component of corporate oversight rather than a peripheral narrative supplement to financial reporting.

3.2 The Expansion of Data Demands Across Value Chains

While binding reporting obligations under the CSRD primarily apply to large undertakings, the directive's operational logic extends beyond formally regulated entities. The requirement for large firms to disclose information on value chain risks, environmental impacts, and social due diligence generates a cascading need for sustainability-related information from upstream and downstream partners (European Parliament & Council, 2022).

Large corporations subject to mandatory reporting increasingly rely on suppliers, subcontractors, and service providers to deliver granular inputs necessary to fulfil their own disclosure and compliance obligations. As a result, small and medium-

sized enterprises are drawn into reporting processes through contractual, commercial, and relational mechanisms (Ligorio et al., 2025).

Beyond supply chain transmission, financial intermediation further reinforces these dynamics. Regulations on sustainable finance, taxonomy alignment requirements, and ESG-based risk assessment practices influence lending decisions and investment flows (Crona et al., 2025). Financial institutions, in turn, request sustainability-related inputs from corporate clients, including SMEs, to meet prudential and disclosure standards. ESG information thus circulates through both production networks and financial channels, strengthening indirect linkage mechanisms (OECD, 2023; Suhatmi et al., 2024).

The expansion of information needs across value chains reflects a system-level transformation in which sustainability reporting operates as a networked governance arrangement extending beyond formally regulated entities (Hummel & Jobst, 2024). Within this system, SMEs become positioned as key providers of information within reporting processes. This transformation lays the groundwork for understanding how ESG-related expectations materialize even in the absence of direct legal mandates.

3.3 Recalibration and Proportionality: Omnibus and VSME

As sustainability reporting requirements expanded in scope and complexity, concerns emerged regarding administrative burden, proportionality, and implementation feasibility, particularly for smaller enterprises indirectly affected by cascading information requests. In response, the European Commission introduced the 2025 Omnibus legislative package, aiming to streamline sustainability-related legislation and recalibrate the balance between regulatory ambition and practical feasibility (European Commission, 2025b).

The Omnibus initiative recognizes that, while harmonization and comparability remain key objectives of EU sustainability governance, reporting arrangements must be proportionate to an organization's capacity. Simplification efforts and clarifications are intended to reduce excessive compliance burdens without compromising transparency objectives.

Parallel to the Omnibus reforms, the introduction of the Voluntary Sustainability Reporting Standard for SMEs (VSME) represents a targeted attempt to address the specific needs of smaller enterprises (European Commission, 2025a). The VSME approach offers a simplified and proportionate reporting structure designed to harmonize information requests and reduce duplication across value chains (EFRAG, 2024). By providing a common reference point, it seeks to alleviate the interpretative uncertainty and administrative fragmentation that SMEs encounter when responding to diverse ESG-related expectations.

Taken together, the Omnibus package and the VSME initiative signal a shift from regulatory expansion toward proportional adjustment. However, even as simplification efforts progress, the systemic involvement of SMEs in the sustainability information architecture remains a defining feature of the European model (Hummel & Jobst, 2024). Understanding this development requires a systematic examination of the determinants shaping ESG-related information requirements at the SME level, an analytical task undertaken in the following section.

3.4 Synthesis: The Structural Evolution of ESG Data Governance in the EU

The evolution of ESG-related information requirements in the European Union reflects more than a gradual increase in disclosure obligations. It represents a system-level transition from voluntary corporate communication toward a distributed information governance arrangement characterized by regulatory standardization, value chain transmission, and proportional recalibration (Breijer et al., 2024).

Initially, sustainability disclosure functioned primarily as a voluntary and reputational practice. With the introduction of binding non-financial reporting obligations, regulatory institutionalization reshaped disclosure into a formal compliance domain. The subsequent adoption of the CSRD extended this logic by situating sustainability reporting within standardized governance arrangements and explicitly incorporating value chain considerations. As reporting expectations cascaded across organizational boundaries, SMEs became indirectly incorporated into the sustainability information system. More recently, simplification initiatives such as the 2025 Omnibus package and the Voluntary Sustainability Reporting Standard for SMEs (VSME) have signaled an effort to balance regulatory ambition with administrative feasibility.

Table 1 summarizes these developmental phases and their implications for SMEs.

Table 1: Structural Phases of ESG Data Governance in the EU

Phase	Core Shift	Implication for SMEs
Voluntary Disclosure	Narrative, flexible sustainability communication	Limited and optional engagement
Regulatory Institutionalization	Legal obligation for large firms (NFRD → CSRD)	Indirect exposure through regulated partners
Value Chain Integration	Cascading ESG data demands across networks	SMEs become upstream data providers
Recalibration & Proportionality	Simplification efforts (Omnibus, VSME)	Recognition of capacity constraints and the need for harmonization

Source: Author’s own elaboration based on NFRD (Directive 2014/95/EU), CSRD (Directive (EU) 2022/2464), the European Sustainability Reporting Standards (ESRS), and the European Commission’s 2025 Omnibus legislative package and VSME framework.

As illustrated in Table 1, SME exposure to ESG data requirements is not primarily the result of direct legal targeting but of structural spillovers embedded within the evolving EU sustainability architecture. This evolutionary perspective highlights the need to examine the mechanisms that generate and shape ESG-related information demands at the SME level. The following section develops a framework based on determinants to systematically analyze these mechanisms.

4

Conceptual Framework: Determinants of ESG Data Requirements for SMEs

4.1

Regulatory Determinants

Regulatory determinants originate in formal legal provisions and governance arrangements that indirectly extend transparency expectations beyond entities explicitly subject to mandatory reporting (Gardner et al., 2019). The transition from the Non-Financial Reporting Directive (NFRD) to the Corporate Sustainability Reporting Directive (CSRD) illustrates how legal architecture reshapes informational dependencies within the European economy. Although binding obligations primarily apply to large undertakings, value chain reporting requirements, due diligence provisions, and standardized disclosure formats generate data needs upstream and downstream.

This mechanism operates through structural interdependence. Corporations subject to detailed sustainability requirements must obtain reliable, verifiable information from suppliers, subcontractors, and service providers to fulfil their obligations. Smaller enterprises, therefore, become incorporated into documentation and verification processes without being directly regulated. The extension of reporting logic is thus embedded in the design of the regulatory framework itself.

A further regulatory dimension concerns proportionality and recalibration. Simplification initiatives, including the 2025 Omnibus package and the Voluntary Sustainability Reporting Standard for SMEs (VSME), acknowledge capacity constraints among smaller firms. Nevertheless, these measures do not reverse integration; instead, they refine its implementation. Regulatory determinants, therefore, function through scope expansion, harmonization, and rule-based standardization, shaping the informational environment in which SMEs operate.

4.2 Market-Based Determinants

Disclosure-related pressures are also transmitted through market relationships. Large corporations increasingly incorporate environmental and social criteria into procurement policies, supplier screening, and contractual requirements (Diebel et al., 2024; Vandenburg & Moore, 2022). Through these mechanisms, sustainability expectations diffuse across production networks and become embedded in commercial exchange. Relational dependence and reputational considerations reinforce such dynamics.

Financial intermediation represents an additional transmission channel. Sustainable finance regulation, taxonomy alignment, and ESG-oriented credit risk assessment influence lending decisions and capital allocation (Li et al., 2025). Financial institutions require structured non-financial information to evaluate exposure and long-term risk, which in turn leads to additional information requests directed at corporate clients, including SMEs. Access to finance thus becomes linked to the capacity to provide credible sustainability-related data.

Market-based determinants differ from statutory mechanisms in that they operate through economic incentives and relational dependence rather than direct legal enforcement. However, their practical impact can be substantial, particularly in sectors characterized by concentrated buyer power or capital intensity.

4.3 Organisational Determinants

Internal capabilities mediate the effects of external expectations. Organizational determinants refer to a firm's capacity to generate, structure, and interpret non-financial information (Geerts et al, 2021). Managerial expertise, governance formalization, digital infrastructure, and prior exposure to certification regimes influence how sustainability-related demands are absorbed and operationalized (Li & Zhang, 2024).

Many smaller enterprises operate with lean administrative structures and limited specialization. Data collection may be fragmented, responsibilities may be diffuse, and documentation practices may be informal. Under such conditions, even modest reporting requests can generate disproportionate strain. Conversely, firms integrated into international supply networks or accustomed to compliance-driven environments may possess routines that facilitate adaptation (Wojtaszek et al., 2025).

Interpretative capability constitutes an additional internal dimension. Regulatory texts and sustainability standards must be translated into operational processes. Divergent understandings of materiality, proportionality, and relevance can produce heterogeneous implementation outcomes. Consequently, integration into the broader sustainability governance system is shaped not only by external pressures but also by organizational readiness and absorptive capacity.

5 Translating EU-Level Governance to SME Practice: The Hungarian Case

5.1 Structural Characteristics of Hungarian SMEs

Hungary provides a revealing context for examining how EU-level sustainability governance materializes within an SME-dominated economy, where micro- and small-sized enterprises account for approximately 99% of all firms and employ

around two-thirds of the workforce (OECD, 2025; European Commission, 2024a). These firms typically operate with lean organizational structures, centralized decision-making, and limited administrative specialization. As a result, formalized internal systems are often less developed, particularly beyond statutory financial accounting. This is especially evident among micro-enterprises that often lack dedicated administrative or sustainability-related functions (Lámfalusi et al., 2024). In addition, Hungarian SMEs lag behind the EU average in terms of digitalization, particularly in the adoption of advanced data management systems, which constrains their ability to respond to structured ESG-related information requests (European Commission, 2024a).

These structural features directly affect the organizational determinants identified in the conceptual framework. Data generation processes frequently rely on ad hoc documentation practices rather than integrated information systems. Responsibility for non-financial matters is rarely institutionalized in dedicated roles, and sustainability considerations may remain embedded in informal managerial routines rather than codified procedures. As a result, the capacity to respond to structured, comparable, and audit-ready information requests varies significantly across firms.

In addition to administrative capacity constraints, interpretative divergence plays a crucial role. Regulatory terminology related to double materiality, due diligence, and governance integration must be translated into operational practice. For many Hungarian SMEs, such concepts are unfamiliar or perceived primarily as externally imposed compliance expectations. This interpretative gap can lead to inconsistent implementation, over-reporting in some cases, and minimal engagement in others (European Commission, 2024b).

Consequently, the embedding of Hungarian SMEs into the EU sustainability architecture is mediated by limited institutionalization, uneven digitalization, and varied levels of strategic assimilation of sustainability considerations. These characteristics amplify the practical implications of externally generated information demands.

5.2 Value Chain Embeddedness and ESG

While internal capacity shapes responsiveness, external positioning determines exposure. The Hungarian economy is deeply embedded in European production networks, particularly in manufacturing-intensive sectors such as automotive, electronics, and industrial services. A substantial share of domestic SMEs operate as suppliers to multinational corporations, particularly in export-oriented manufacturing sectors that account for a significant proportion of Hungary's industrial output (Éltető, 2025; OECD, 2023).

This transnational embeddedness activates the regulatory and market-based determinants outlined earlier. Large corporations subject to CSRD obligations increasingly require detailed environmental and social information from upstream partners to ensure compliance with value-chain disclosure and due diligence requirements. In parallel, ESG-oriented procurement standards and supplier evaluation systems further formalize sustainability expectations within commercial relationships.

Financial intermediation reinforces these dynamics. Hungarian SMEs seeking credit from domestic or EU-affiliated banks increasingly encounter ESG-related information requests as part of risk assessment processes, reflecting the growing integration of sustainability criteria into financial supervision and lending practices (Magyar Nemzeti Bank, 2024). Although not directly bound by reporting directives, firms may be required to provide structured data on emissions, energy use, governance practices, or supply chain risks to secure financing or maintain long-term contractual relationships.

The Hungarian case thus illustrates a dual condition: structural vulnerability combined with deep incorporation into European economic networks (Lux, 2025). On the one hand, many firms possess limited formalized reporting capacity. On the other hand, their participation in cross-border value chains exposes them to cascading informational expectations (Lámfalust et al., 2024). This combination renders Hungary an analytically relevant context of how EU-level sustainability governance diffuses beyond its formal regulatory perimeter and becomes operational at the SME level.

6 Discussion of the Results

The findings confirm that the growing exposure of small and medium-sized enterprises to sustainability-related information demands within the European Union is not an accidental result of regulatory expansion but the outcome of a deeply embedded governance logic. The shift from voluntary disclosure practices to a unified, assurance-backed reporting system has made sustainability transparency a fundamental part of European economic coordination. While binding legal obligations mainly target large corporations, the structure of the regulatory framework creates informational dependencies that extend far beyond the officially specified reporting scope. The move from the NFRD to the CSRD signifies more than just an increase in disclosure requirements; it represents a significant shift in how sustainability reporting functions as a governance tool. By incorporating value chain accountability, due diligence expectations, and standardized reporting formats into legal requirements, the regulatory setup establishes structural links between regulated companies and their business partners. These links produce continuous information flows that pull SMEs into documentation, verification, and risk management activities, even when the law does not directly target them. In this way, integration happens through the design of the framework rather than through explicit designation.

The determinant-based framework developed in this study clarifies how these dynamics operate. Regulatory spillovers create the initial conditions by expanding the informational scope of large-firm disclosure. Market-based transmission mechanisms—most notably supply chain governance and financial intermediation—translate these legal expectations into operational requests. Contractual requirements, procurement standards, and ESG-oriented credit assessments function as conduits through which sustainability-related demands are relayed to smaller enterprises. Organizational capacity constraints then mediate how such pressures are experienced and managed. The interaction of these three determinant groups explains why SMEs encounter escalating expectations despite remaining outside the core regulatory perimeter.

A central contribution of the analysis lies in identifying the qualitative deepening of reporting logic as a pivotal transformation. Early disclosure practices focused primarily on metric-based transparency. In contrast, the current framework

increasingly emphasizes governance processes, risk oversight structures, policy formalization, and due diligence systems. For smaller enterprises, this shift has disproportionate implications. While quantitative indicators may require technical measurement, governance-oriented expectations demand procedural formalization and institutional restructuring. The burden, therefore, extends beyond data collection toward organizational redesign. This transformation intensifies the structural tension between regulatory ambition and administrative feasibility that has motivated proportionality initiatives such as the Omnibus package and the VSME framework.

The Hungarian case illustrates how these structural dynamics materialize within an SME-dominated economic environment. Hungary's deep integration into European production networks activates both regulatory and market-based determinants. Multinational corporations operating under CSRD obligations transmit sustainability-related requirements upstream, while financial institutions increasingly incorporate ESG risk considerations into lending practices. At the same time, many Hungarian SMEs operate with limited formalization, fragmented data systems, and uneven clarity in interpreting regulatory expectations. The result indicates a misalignment between exposure and organizational readiness. Rather than being gradual and internally driven, integration appears largely externally driven, with external requirements shaping it rather than internally initiated strategies.

This configuration supports conceptualizing SMEs as structurally embedded actors within a distributed sustainability data regime. Their role is neither peripheral nor purely voluntary; instead, they serve as upstream information providers and risk-transmission nodes within an interconnected reporting structure. However, the depth of inclusion varies according to organizational readiness. Where internal systems are underdeveloped, disclosure-related pressures generate strain and uncertainty. Where routines and governance structures are more advanced, adaptation is comparatively smoother. The Hungarian example thus demonstrates how macro-level regulatory transformation interacts with meso-level market dynamics and micro-level organizational capacity.

Figure 1 synthesizes these findings by depicting the interaction between regulatory architecture, market transmission channels, and internal capability as a dynamic system. The model highlights that informational expectations originate at the

regulatory level, are operationalized through commercial and financial relationships, and are ultimately absorbed—or resisted—within firm-level structures. Effective integration occurs when organizational capacity aligns with external pressures; structural tension emerges when exposure exceeds readiness.

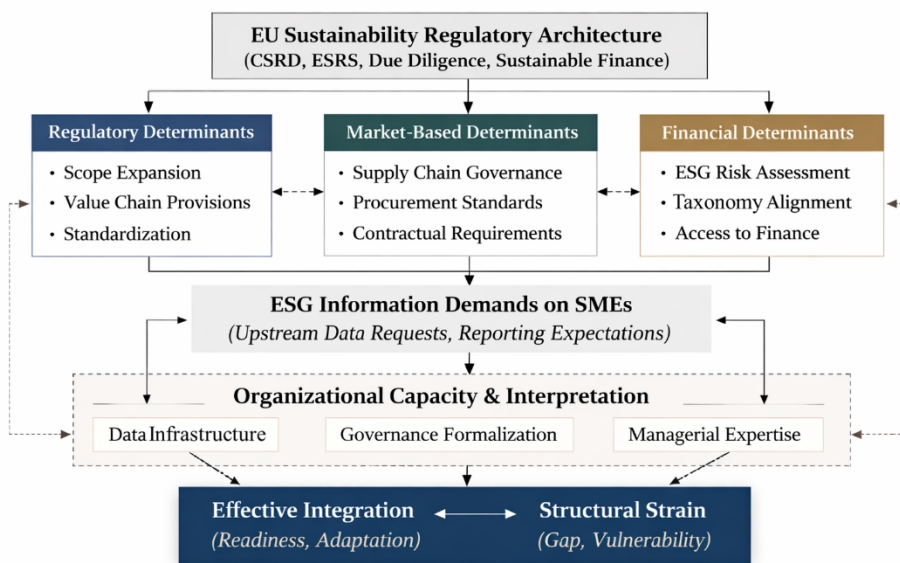


Figure 1: Determinant Interaction Model of SME Incorporation into EU Sustainability Governance
Source: Author’s own elaboration

Taken together, the results refine existing understandings of the diffusion of sustainability governance. Rather than a linear extension of compliance obligations, the European model operates through layered interdependencies that redistribute informational responsibility across economic networks. SMEs are incorporated not by explicit regulatory targeting but through relational and systemic mechanisms. This indirect structural integration reshapes their strategic environment, altering documentation practices, governance arrangements, and interactions with business partners and financiers. The implications extend beyond administrative burden, touching on competitiveness, resource allocation, and long-term organizational transformation.

7 Conclusions and Further Research Steps

7.1 Conclusions

This study examined how ESG-related information requirements affecting small and medium-sized enterprises have evolved within the European Union and identified the key determinants shaping this process. The findings indicate that the increasing exposure of SMEs to sustainability reporting expectations is not primarily driven by direct regulatory obligations, but rather by the underlying design of the EU sustainability governance system. Through regulatory spillovers, value chain transmission mechanisms, and financial intermediation processes, SMEs become embedded in a distributed data governance environment despite remaining largely outside the formal scope of mandatory reporting.

The Hungarian case illustrates how these dynamics materialize within an SME-dominated economy characterized by limited formalization and uneven preparedness. The combination of strong value chain integration and constrained internal capacities creates a persistent tension between regulatory ambition and administrative feasibility. Although recent initiatives such as the Omnibus package and the Voluntary Sustainability Reporting Standard for SMEs (VSME) aim to improve proportionality, they do not fundamentally alter the embedded position of SMEs within the evolving sustainability architecture.

7.2 Theoretical Contributions and Policy Implications

From a theoretical perspective, this study contributes to the literature in three main ways. First, it introduces the concept of indirect system-level integration to explain how SMEs become incorporated into sustainability reporting systems without explicit regulatory targeting. Second, it identifies a qualitative shift in reporting logic from metric-based disclosure toward governance-oriented practices, including due diligence, risk management, and strategic alignment. Third, it demonstrates that the effects of regulatory expansion are mediated by organizational capacity, interpretative clarity, and institutional context, thereby linking regulatory design with firm-level implementation processes.

From a policy perspective, the findings underline the importance of proportionality in sustainability reporting arrangements. While instruments such as the VSME represent important steps toward harmonizing expectations and reducing administrative burden, effective implementation requires more than regulatory adjustment. Capacity-building initiatives, clearer guidance, and institutional support mechanisms are essential to enhance SMEs' ability to generate, interpret, and manage ESG-related information. Without such support, the gap between regulatory expectations and organizational readiness is likely to persist.

7.3 Further Research Steps

This study opens several directions for future research. Empirical investigations are needed to assess how the identified determinants interact across sectors, firm sizes, and national contexts. Comparative analyses could help determine whether the Hungarian case reflects a broader regional pattern or a more general feature of SME-dominated economies. Further research may also explore the role of digitalization and artificial intelligence in reducing reporting burdens and strengthening information-generation capabilities. In addition, longitudinal studies could examine whether recent proportionality-oriented reforms effectively alleviate system-level pressures or primarily redistribute them across value chains.

By conceptualizing SMEs as institutionally embedded actors within a multi-level sustainability governance system, this study contributes to a more nuanced understanding of how European regulatory ambition reshapes economic organization beyond its formal boundaries. The long-term effectiveness of the EU sustainability reporting model will depend not only on regulatory refinement but also on the alignment between governance expectations and organizational capacity at the SME level.

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DIGITAL RESILIENCE IN THE AGE OF AI: THE ROLE OF MEDIA AND INFORMATION LITERACY (MIL) IN EMPOWERING GEN Z AND ENHANCING ESG OUTCOMES

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A coherence between media and information literacy (MIL), digital resilience, empowerment of Gen Z, and Environmental Social Governance (ESG) could be seen as a complex contemporary phenomenon in the context of the development of Artificial Intelligence (AI), when MIL acts a structural mechanism, which enables Gen Z to become digitally resilient and influence ESG outcomes accordingly. Empirical research on MIL in Lithuanian Gen Z individuals aged 16-19 and 20-24 revealed a moderate level of MIL, which further increases in the group of 20-24 years old. However, research results revealed that the respondents tend to be less reactive and thus take no proactive efforts, particularly in analysing the digital content from different perspectives or warning others regarding fake news. Recognising the identified gaps in MIL, the study proposes comprehensive solutions through the implementation of ESG-aligned practices aimed at strengthening digital resilience among Gen Z.

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1 Introduction

The development of *Artificial Intelligence (AI)* is recognised as a driving force for economies and societies at the global level. Scientific literature emphasises its power to enable organisations to respond more efficiently and proactively to *Environmental, Social, and Governance (ESG)* areas (Hamdouni, 2025; Lulewicz-Sas et al., 2025). ESG framework, which was presented first time in the report “Who Cares Wins: Connecting Financial Markets to a Changing World” (United Nations, 2004), is a set of standards, policies and metrics used by organisations and investors as a crucial measure to assess both the societal and environmental impact of their operations and to shape the future of nations, businesses, and consumers (A guide to ESG: what is it and why does it matter?, 2024; Pérez et al., 2022). For example, *environmental* aspects are reflected through the organisational practices to decrease carbon emissions, energy usage, waste management, and pollution control; *social aspects* could be visible through the company’s relationships with employees, suppliers, customers, and communities, covering aspects such as labour practices, human rights, and community engagement; and finally, *governance* aspects may be reflected in the quality of corporate governance, including the structure and behaviour of the board of directors and shareholder rights (Krishnan, Yang & Tan, 2024).

While implementing progressive AI based machine learning, predictive analytics and automation tools, organisations can increase productivity, innovation capacity, organisational efficiency and, in ESG terms, they maintain their environmental and social responsibility, and governance quality and robustness (Lulewicz-Sas et al., 2025; Hamdouni, 2025).

It is worth noting that AI also significantly impacts the media and information contents, and the ways in which they are created, processed and interpreted (Sergeeva et al., 2025). Although AI may be used to generate novel content of high quality, such as images, text, or music for positive purposes, AI is also employed to produce *fake news* in such ways that the detection of misleading or even harmful information becomes very complicated (Devrim, 2025). Thus, AI as a powerful tool is also being used to fabricate ESG outcomes, when organisations emphasise their commitment to sustainability at economic, social and /or ecological levels, including implementing *greenwashing* techniques, i.e. vague /false statements about

sustainability practices (Di Pillo, Palombi & Strazzullo, 2025). The society, in return, positively evaluates organisations, which plan, implement and monitor the revelation of ESG outcomes in their organisational processes.

It should be stated that the generation of *Gen Z*, which consists of the individuals who are born between 1997 and 2012, is significantly interested in personalised experiences that align with ESG values (Cao et al., 2026). These values are reflected in “organisational ecological environment, its coexistence and interaction with human and other populations, and the corporate system of internal control and procedures” (Lulewicz-Sas et al., 2025, p. 635). The choice of ESG based values among Gen Z could be noticed not only from a customer but also from employee perspective - for example, the scientific research of Lulewicz-Sas et. al. (2025) revealed that employees are more engaged if society and corporate governance-related ESG are in place.

On the other hand, since Gen Z literally grew up with digital technologies, it is very familiar with various digital tools and welcomes AI-driven experiences well (Cao et al., 2026). In addition, Gen Z individuals especially are dealing with huge amounts of data and information and thus experience various challenges in managing and acting upon them. Patel et al. (2025) note that the exposure to false or misleading information significantly influences Gen Z individuals because they might accidentally create and share misinformation without even realising it (Zagni & Canetta, 2023). Thus, we need to employ *MIL* as the fundamental defence against these challenges because it allows people to doubt human and AI-generated content (Devrim, 2025). In scientific literature media literacy traditionally is defined as “the ability to encode and decode the symbols transmitted via media and synthesise, analyse and produce mediated messages” (National Association for Media Literacy Education, n.d.). By enhancing MIL, individuals can navigate the digital ecosystem more responsibly, avoiding the negative impacts (Susilawati, Halfiani & Wahyuni, 2024).

It may be argued that Gen Z, despite its significant digital involvement, doesn't possess good digital MIL skills (Gherguţ-Babii, Poleac & Obadă, 2025; Mercenier, Wiard & Dufrasne, 2021). Young individuals access the information easily but are not able to evaluate critically or they may use media only for social connections (Susilawati, Halfiani & Wahyuni, 2024). Accordingly, digital naivety causes a

vulnerability gap, which creates risks for cyberbullying, misinformation, and other digital harms. Such a context requires the employment of MIL in such a way that it leads to *digital resilience*.

We state in this Chapter that MIL, which leads to digital resilience, is supposed to act as an empowerment tool of Gen Z to enhance ESG outcomes because of Gen Z attitudes to sustainability.

Empowering Gen Z individuals is challenging because of dual obstacles: their limited skills concerning MIL and a macro environment which lacks support for ESG based values. For example, weak environmental awareness, social polarisation and instability, challenges to good governance, lack of transparency etc. can be seen among the examples of disabling macro environment. Various digital technologies including AI, while used to produce fake news, also do their harm in damaging public trust and decreasing stability of information ecosystems and democratic systems (Patel, Jain & Mathew, 2025). Thus, **a research question** is formulated as follows: How to empower Gen Z to enhance ESG outcomes through MIL leading to digital resilience in the context of AI?

Exploring the solutions to this research question is quite challenging as a significant gap in terms of availability of scientific literature exists in establishing the relationships between i) AI and ESG outcomes (Hamdouni, 2025), ii) MIL and ESG outcomes, while MIL itself is more portrayed as a cognitive skill (Blumberg et al., 2017), which is a quite static approach but not a dynamic approach considering the need for digital resilience and empowerment of Gen Z. Finally, empowerment itself should be understood as a complex phenomenon. Considering these statements, **we are aimed** at presenting the complex phenomenon of MIL, digital resilience, Gen Z empowerment and ESG outcomes by adapting a multilayer interdisciplinary approach. The research is organised as follows: the first section provides theoretical insights regarding MIL, digital resilience, Gen Z empowerment and ESG outcomes; the second section presents research methodology of empirical research on MIL vulnerability among Gen Z in two different groups 16-19 years old and 20-24 years old; the third section presents the empirical results of the performed research, while the section of Discussion also presents a conceptual framework regarding interconnections of MIL, empowerment of Gen Z, and digital resilience.

2 Literature Review

2.1 Media and information literacy (MIL) as a competence to tackle fake news

The topic of *media and information literacy (MIL)* is gaining more significance during the years. It is being emphasised and evaluated in various strategic documents at European Union and national levels since MIL is one of the prerequisites of successful and qualitative digital education. Because of its significance, MIL is called the foundational skill for democracy in the 21st century (Boyd & Dobrow, 2011; Jolls & Johnsen, 2017) to deal with fake news. MIL enables individuals to evaluate information, recognise fake news, and make informed choices (Gherguț-Babii, Poleac & Obadă, 2025).

Fake news, which as the term first emerged in 2016 during U.S. presidential election (McDougall, 2019), could be defined as inaccurate, false, or grossly distorted information (with no verifiable facts, sources or quotes to deceive the audience (Obadă & Dabija, 2022; University of Michigan Library, n.d.). Fake news can be divided into three types of information disorder, such as misinformation, disinformation and mal-information, and seven forms of manifestation, such as satire or parody, false connection, misleading content, false context, imposter content, manipulated content and fabricated content (The Commons: Social Change Library).

Misinformation is false information that is created and spread without an intention to harm or deceive ((The Commons: Social Change Library).). Misinformation could be recognised in spreading incorrect rumours; jumping to conclusions, accidentally relying on bad sources (Gunner, 2021). According to Ackland & Gwynn (2020), misinformation also includes satire news, conspiracy theories and hoaxes, which may be humorous or malicious, and often involve citing a trusted source.

Disinformation, on the contrary, spreads with the intention to deceive or cause harm (The Commons: Social Change Library). Disinformation reveals itself in starting untrue rumours, leaving out details and intentionally using bad sources (Gunner, 2021)

Finally, *mal-information* is deliberate publication of private information for personal, corporate or political, rather than public interest (The Commons: Social Change Library).

Fake news can be analysed through a shared network, aimed group and focused area. The area mostly includes animals, celebrities, food and diets, body image and sexuality, beauty and fashion, health, shopping, technology, crime and politics (Examples of Fake News Relevant for Young People, 2019). MIL—the ability to critique, understand, and analyse media—plays a crucial role in mitigating the effects caused by negative news (Susilawati, Halfiani & Wahyuni, 2024). According to Devrim (2025), media literacy functions through four operational dimensions which enable users to access content and use it and analyse it critically and generate new content and produce ethical creative work.

In the age of AI, MIL has a significant emphasis on the digital aspect. Thus, *digital* MIL encompasses skills related to accessing, navigating, and interpreting information across digital platforms and thus it is essential for effective usage of AI technologies (Sergeeva et al., 2025). Digital MIL includes three core aspects: *technical literacy* (proficiency in using digital tools), *cognitive literacy* (critical thinking and reasoning), and *socio-emotional literacy* (responsible and ethical online behaviour) (Ng 2012; Suwanto, Setiawan & Machmiyah, 2022). According to Perdana et al. (2019), essential elements of digital literacy include critical thinking, creativity, information assessment, and proficient utilisation of digital media.

One should state that Gen Z individuals, which are competent in MIL, may enhance ESG outcomes only if their MIL skills make them digitally resilient. Following Park et al. (2024) statement that “*resilience-based approaches seek to maintain people’s autonomy and ability to self-regulate when facing harms, instead of paternalistically shielding them from encountering risk*”, it is obvious that only *proactive* behaviour towards fake news impacts positively ESG outcomes.

2.2 Media and information literacy as an empowerment tool for Gen Z to enhance ESG outcomes

In general terms, **empowerment** encompasses individuals' autonomy in decision-making regarding duties and tasks (Khany & Tazik, 2016). In this Chapter, we are concentrating on two main types of empowerment - **structural** and **psychological**. At the organisational level, structural empowerment focuses on policies and practices to direct power, decision-making authority and responsibility to lower levels of the organization (Sun, Zhang & Chen, 2012). In other words, we mean various conditions that are provided for individuals to perform a particular task using their own autonomy. In the case of ESG outcomes, an organisation implemented the structures and processes, based on ESG metrics, which encourage to behave sustainably at ecological, social and environmental levels. Choi, Jeong & Park (2024) confirmed that ESG activity recognition has a positive relationship with self-efficacy and empowerment of employees to use their autonomy for decision-making. At a wider level, the structural empowerment of ESG systems means that, for example, the governments create mandatory reporting standards, frameworks that align economic growth, community /societal needs, environmental preservation with sustainability. In the case of digital dimension (MIL and digital resilience), structural empowerment is based on officially creating transparent, ethical practices, systems and procedures to fight fake news and increase societal MIL.

Structural empowerment is supposed to increase **psychological empowerment of individuals**, which Llorente-Alonso, García-Ael & Topa (2023) sees as “a subjective, cognitive, and attitudinal process that helps individuals feel effective, competent and authorized to carry out a task”. Psychological empowerment consists of the following factors - *meaning* (the value seen in implementing tasks or goals); *competence* (to fulfil the tasks); *self-determination* (or autonomy), and *impact* (the degree to which behaviour is seen as “making a difference”) (Spreitzer, 1995; Khany & Tazik, 2016; Sun, Zhang & Chen, 2012).

The current context doesn't seem very empowering to enhance ESG outcomes from a Gen Z perspective. According to McDougall (2019), in the Digital Era 4.0, the amount of dissemination of negative news, such as reports on violence, corruption, kidnapping, pornography, hate speech, and bullying, through digital platforms like Instagram, Twitter, TikTok, Facebook, and Telegram, seems very concerning. It is

even more concerning because society in general likes negative news (Susilawati, Halfiani & Wahyuni, 2024) but Generation Z, immersed in digital media from a young age, is particularly vulnerable to the psychological effects of such exposure (McDougall, 2019).

The influence of older generations may also not always be positive because older generations don't possess good MIL skills although they consume a lot of data and information (McDougall, 2019) presented through social media platforms - Pariser (2011) states that it creates "filter bubble" phenomenon, when the provision of algorithm driven information limits the exposure of other beliefs and opinions, and other opinions are unheard.

Low digital MIL among individuals also impacts lower levels of *civic engagement* (Gherguț-Babii, Poleac & Obadă, 2025) and it explains why sometimes a significant proportion of the society is not motivated to influence the changes. Gen Z is seen as the generation that it is not interested in political matters, such as voting. We could state that if Gen Z individuals deal with data and information in passive ways, they will be less interested in civic engagement, and in return it increases their vulnerability to fake news, as they lack the critical MIL necessary to discern credible sources from false information (Gherguț-Babii, Poleac & Obadă, 2025). The vulnerability to fake news increases because Gen Z also is searching for the confirmation of credibility among peers rather than researching traditional, scientific ways (Hassoun et al., 2025).

According to Maulana et al. (2024), engaging youth in media initiatives and educational schemes may positively impact their engagement in activities regarding environmental protection, benefiting both youth and ecosystems because MIL influences individuals' understanding of ecological issues, and thus shaping environmental awareness. It could be stated that MIL contributes to the development of eco-media literacy (López, 2023) with its deeper insights into environmental impacts.

However, although Gen Z is closely connected to environmental and social approaches, its insufficient MIL skills restrict digital resilience and the manifestations of ESG based behaviour because such a behaviour requires critical accessing and evaluation of data and information, distinguishing real sustainable initiatives from

greenwashing and other misinformation, taking initiative to encourage sustainable behaviour at different levels.

3 Media and information literacy (MIL) among Gen Z: manifestations and challenges

This section presents research methodology to evaluate MIL among Gen Z and empirical research results to present the manifestations of MIL among Gen Z in the following age groups – 16-19 years old and 20-24 years old.

3.1 Research methodology to evaluate media and information literacy (MIL) among Gen Z

Pilot research was performed to evaluate disinformation vulnerability of 9-12 grade students (16-19 years old) in Lithuanian secondary education institutions (secondary schools, gymnasias and vocational education institutions, which provide the secondary education) and young students between 20-24 years old, which should already have more competence and skills to evaluate news on the media. It was expected to collect at least 100 fully answered questionnaires for exploratory purposes.

The Lithuanian media literacy index, which is calculated by Open Society Institute Sofia, is 58 points out of 100 points in 2026 (Open Society Institute Sofia, 2026). This index is the same as in 2022 (Łessenski, 2022). The highest media literacy index in 2026 belongs to Denmark, Finland, Ireland and Netherlands (71 points for each of these countries). Although Lithuania is not doing badly being in the second cluster of countries, the index still doesn't change, and the media literacy index looks average. These reasons show the importance of researching Lithuanian context.

The Assessment tool – questionnaire, which was used in the research, was created in the Project SPOTTED, where we both, the Authors of the Chapter, were part to (Herrero-Diz & Muñiz-Velázquez, 2022). This questionnaire served to meet the following research objectives regarding Gen Z in the age groups - 16-19 years old and 20-24 years old, as follows: 1) to analyse how much the research participants provide credibility to information or news they receive from social networks, Internet or the smartphone in basic checking (6 items-statements), quantitative

reading level (4 items-statements), qualitative reading level (4 items-statements) and understanding the purpose of a particular news (5 items-statements); 2) to analyse the sharing of any information or news received on social media, Internet or mobile phone (6 items-statements).

The respondents were asked to evaluate each statement by 5 point-Likert scale, by choosing among “1 Never / 2 Rarely/ 3 Sometimes/ 4 Usually / 5 Always”. It is important to note that the respondents were received a Lithuanian version of the questionnaire.

The questionnaire was developed in the online format with a link to share in the secondary, vocational and higher education institutions under the permission of their heads. In the case of students until 18 years old, the parental permission to be a part of research had to be received. The educational institutions organised this process.

The questionnaire was anonymous - no personal data, which could help us to identify the respondents were collected. The respondents were supposed to only mention their age, gender (male/female/other), city and study institution type (secondary, vocational, higher education).

In the beginning of the questionnaire, the respondents were provided with an explanation in a written form that the participation in the research is voluntary and the respondents are permitted to withdraw whenever they want, without having to give explanations; that all data obtained in the study will be anonymous and will be used only for the research purposes. In addition, it was emphasised that only the respondents 16 years of age or older are supposed to participate in the research.

The respondents were also provided with a contact (kristina.grumadaite@ilk.lt) to ask any questions regarding this research.

3.2 Empirical research results as reflection for a need of digital resilience

From 147 received answered questionnaires, 91 questionnaires were fully answered. 38 % of respondents simply stopped in between or even in the final stage of the questionnaire without evaluating all the statements. We assume that this

questionnaire was quite long for Gen Z. However, only fully answered questionnaires were used for further analysis.

57 fully answered questionnaires in the age group of 16-19 years old were collected. The questionnaire was performed by 22 males, 33 females, neither men nor women - 2. The most of respondents were from Kaunas district (30), the rest were from Utena district (3), Telšiai district (7), Šiauliai district (2), Klaipėda district (7), Marijampolė district (4), Panevėžys district (3), Alytus district (1).

In comparison, 34 fully answered questionnaires from the respondents who are more than 20 years old but no more than 24 years old, were collected. 67.65 % of them are from Kaunas city (Lithuania). 21 of the respondents were women.

We didn't notice any differences among the answers in the case of city, gender or the type of educational institution, most of the differences were noticed while analysing both age groups. Thus, further presentation of data is concentrating on the age factor.

Table 1: Basic checking

		Often or always (16- 19 years old)	Often or always (20-24 years old)	Rarely or never (16- 19 years old)	Rarely or never (20- 24 years old)
1.	I check if the author of the content or news is there.	38,60 %	58,82 %	33,33 %	20,59 %
2.	I look to see if the website or the medium is known.	47,40 %	70,59 %	15,79 %	2,94 %
3.	I verify that the web address is credible.	50,88 %	67,64 %	24,56 %	14,71 %
4.	When it's a video, I check to see who made it.	35,08 %	47,58 %	38,60 %	17,65 %
5.	I look to see if the information is recent.	42,11 %	61,76 %	26,31 %	17,65 %
6.	I check if the photo corresponds to the rest of the content.	43,86 %	58,82 %	24,56 %	11,43 %

Source: Authors' own work

Basic checking. This group of items includes checking the presence of the author of the news and video, credibility of website and web address, coherence of photo and content, and the timing of the news (Table 1). Research results revealed that at

least one third of the respondents, who are 16-19 years old, rarely or never check the existence of the author of the content or news. This situation improves in the age group of 20-24 years old, including the fact that there is no one from this group who never checks the name of the author (only 7 respondents from this age group are doing it rarely) (Table 1).

More positive results among the youth of 16-19 years old are in the case of seeing whether the website is known: 47,40 % of respondents are doing it always or often, while only 15,79 % of respondents are doing it rarely or never.

The situation even more improves in the case of respondents, which are more than 19 years old. 70,59 % of respondents mentioned that they are doing this often or always. Only one of them never does it.

50,88 % of respondents (16-19 years old) verify the credibility of a web address, while 24,56 % of respondents are doing it rarely or never.

In the case of the respondents who are more than 19 years old, 67,64 % of them always or often verify the credibility of a web address, while only five respondents are doing it rarely or never (14,71 %).

A concerning situation is seen in the case of checking the author of the video. 38,60 % of respondents (16-19 years old) do it never or rarely; 26,32 % of respondents do this sometimes.

The respondents, which are more than 19 years old, seem more aware of the necessity to know the author of the video. Only 6 of them (17,65 %) mentioned that they are doing it never or rarely but almost half of the respondents (47,58 %) are doing it always or often.

However, considering that 35,29 % of respondents are doing it sometimes, it shows *that video content is still being taken for granted despite the age group*. In general, we could state that if a respondent doesn't check the author of the video, he /she won't check the author of the news as it is.

In the case of 4th and 5th items, better results of MIL again are seen in the age group of 20-24 years old (Table 1).

Quantitative reading level. This group of items consists of the need to read the entire news or content, finding contacts or other information about the author of the news and comparison of the information with other sources (Table 2). Out of the 4 items, the most concerning results are revealed regarding checking the contacts or other information about the author of the news - only 14,04 % of respondents of 16-19 years old often or always are looking for the contact of the author of the news (Table 2).

Table 2: Quantitative reading level

		Often or always (16- 19 years old)	Often or always (20-24 years old)	Rarely or never (16- 19 years old)	Rarely or never (20- 24 years old)
1.	I need to read the entire news or content.	47,37 %	44,12 %	19,3 %	20,59 %
2.	I look to see if I can contact the author or find more information about him or her	14,04 %	38,24 %	45,61 %	28,76 %
3.	I compare the information with other sources.	31,58 %	58,82 %	28,07 %	20,59 %
4.	I'm good with reading only the headline	24,56 %	38,24 %	31,58 %	32,35 %

Source: Authors' own work

Although the results are better in the case of other items, the overall results are not satisfying because still quite a big number of respondents are not very attentive, don't care much about information comparison and feel quite good reading only the headline, especially in the younger age group (Table 2): for example, **24,56 % (14) of respondents agree that they often or always feel good with reading only the headline. 43,86 % (25) do it sometimes.** 19,3 % (11 respondents) from this age group even don't need to read the content of the entire news. In the case of the latter situation, the respondents of 20 years old or more demonstrate quite similar results.

Qualitative reading level. It includes evaluating reliable sources, proper presentation of the news, timing of the news and expressiveness of the headline (Table 3). Looking at Table 3, almost a half of the respondents from the age group

of 16-19 years old (47,37 %) often or always check the reliability of the sources of the news, while a third of respondents (33,33 %) are doing this sometimes. It is important to note that *there are still some individuals who rarely or never note this*. The results regarding the respondents 20 years old or more seem better, however, there are still some respondents (5 in total), who never or almost never do this.

Table 3: Qualitative reading level

		Often or always (16- 19 years old)	Often or always (20- 24 years old)	Rarely or never (16- 19 years old)	Rarely or never (20- 24 years old)
1.	I note whether the information contains data or figures from reliable sources.	47,37 %	67,65 %	19,3 %	14,71 %
2.	I check whether the information is well presented (without spelling errors, grammatical errors, etc.)	45,61 %	52,94 %	24,56 %	8,82 %
3.	I will doubt a story if the headline is too attention-grabbing.	31,58 %	58,82 %	28,07 %	20,59 %
4.	I think about whether the content I'm receiving is related to the present.	33,33 %	58,83 %	15,79 %	11,76 %

Source: Authors' own work

It is important to note that *only 9 respondents from the age group of 16-19 years old confirmed that they always have the doubt regarding the expressiveness of the headline*, while 24,56 % of respondents are doing it rarely or never. However, regarding respondents of 20 years old or more, the results are the opposite: 64,71 % of respondents always or often have this doubt, and only 5 respondents are doing it never or rarely.

15,79 % of respondents 16-19 years old rarely or never are thinking about whether the content they are receiving is related to the present. *50,88 % are doing it sometimes*, thus it shows that there is a probability to read and even to share the news, which may be outdated

In the case of the respondents 20 years old or more, 11,76 % of the respondents (4 respondents) are doing it rarely or never, 29,41 % of the respondents are doing it sometimes.

Purpose or aim. Table 4 presents the results about the willingness of the respondents to differentiate the context of the news and analyse the impact of it on them and others. Research results reveal that the minority, but still 9 respondents of 16-19 years old age rarely or never can differentiate the possible humorous aspect of the news or content. Even more positive results are seen in the case of respondents of 20 years old or more, while only 3 respondents are doing it never (1 respondent) or rarely (2 respondents).

Table 4: Purpose or aim

		Often or always (16- 19 years old)	Often or always (20-24 years old)	Rarely or never (16- 19 years old)	Rarely or never (20- 24 years old)
1.	I clearly differentiate if the news or content is humorous or a joke.	45,61 %	61,76 %	19,3 %	8,82 %
2.	I think about whether the information is trying to influence my emotions (make me laugh, angry, outraged...)	28,07 %	41,18 %	19,3 %	20,59 %
3.	I analyze whether the content, in addition to informing, has another purpose (political, ideological, economic...).	31,58 %	44,12 %	36,84 %	26,47 %
4.	I think about whether the information is intended to harm someone or something.	33,33 %	70,59 %	26,32 %	5,88 %
5.	I clearly distinguish between what is information and what is opinion.	56,14 %	64,71 %	15,79 %	11,76 %

Source: Authors' own work

The Table 4 also reveals that news analysis skills should be improved - approximately one third of respondents of respondents 16-19 years old don't analyse the purpose and context of the news. *26,32 % of respondents 16-19 years old never or rarely think about the possible harm of the information (15 respondents)*, 33,33 % of

respondents (19 respondents) think about it often or always. The improvement of this aspect is visible among the respondents of 20 years old or more, when 70,59 % of the respondents often or always think about it, and only 2 respondents never or rarely think about it.

Table 5: Dissemination

		Often or always (16- 19 years old)	Often or always (20-24 years old)	Rarely or never (16- 19 years old)	Rarely or never (20- 24 years old)
1.	When information or content amuses me (funny message), I share it immediately, without fact-checking it.	43,85 %	32,36 %	31,59 %	44,12 %
2.	If a news item makes me outraged or angry, I share it immediately, without cross-checking it.	7,02 %	8,82 %	77,19 %	73,53 %
3.	When I get a piece of news that makes me happy, I share it quickly, without having to cross-check it.	45,61 %	41,18%	24,57 %	35,29 %
4.	When sharing content, I simply seek to entertain myself and my friends.	43,86 %	29,41 %	11,76 %	50 %
5.	I share news or content with the main intention of influencing the opinion of others.	15,79 %	11,76 %	61,40 %	70,59 %
6.	If I know it's false, I share it to warn my contacts.	29,82 %	38,24 %	38,60 %	38,24 %

Source: Authors' own work

Dissemination. Table 5 represents the results of the intention to share particular information, and it reveals quite satisfying results regarding the following items:

- *Sharing funny information without fact-checking it.* In the age group of 16-19 years old: always – 6 respondents (10,52 %); often – 19 respondents (33,33 %); sometimes – 24,56 % – of respondents; rarely – 14 respondents, and never – 4 respondents. 32,36 % of respondents of 20 years old or more are doing it often or always, but almost half of the respondents (44,12 %) are doing it rarely (11 respondents) or never (4 respondents).

- *Sharing anger provoking news without cross-checking it.* Most of the respondents of 16-19 years old (35, or 61,40 % of them) **never** do this. Additional 9 respondents are doing it rarely. Only 4 respondents share such news. In the case of the respondents, which are 20 years old or more, 52,94 % of respondents **never** do this.

Although the respondents aren't eager to share anger provoking news, gratifying news is shared more often without fact-checking.

It is also necessary to note that the respondents aren't intended to warn others regarding noticed fake news – only 29,82 % of the respondents in the age group of 16-19 years old always or often share this with others. In general, more than third of the respondents of both age groups never warn others about fake news.

4 Discussion

This Chapter emphasises that ESG includes governance, social and ecological dimensions, which are more directed to organisations, but not to individuals. However, although individuals don't own ESG, they can make an impact on these dimensions, for example, achieving more sustainable and resilient outcomes. In such a sense, micro-behaviour makes an impact on macro behaviour.

The most challenging areas regarding MIL. Empirical research results presented in the Chapter reveals that MIL skills will improve with age: the respondents in the age group of 20-24 years old demonstrated better results in all MIL aspects in comparison to the 16-19 years old age group. The most concerning areas regarding MIL are noticed in 1) (non)checking the availability of the contact and additional information about the author of particular news; 2) reading only headline without reading the entire news; 3) analysing the reliability of the sources of particular news; 4) recognising the over-expressiveness of a particular headline which may be fake; 5) checking the timing of particular news; 6) analysing news context, especially before sharing it with each other.

Reactiveness vs. Proactiveness regarding media. The Dissemination part of empirical research clearly shows the attitudes of Gen Z towards media as a platform to share the news that make them happy (not sad or angry) and allow them to

entertain themselves and their friends, even without cross-checking it. It confirms the statements in the scientific literature that Gen Z uses social media more for joyful communication and consumption (Panagiotou, Lazou & Baliou, 2022) than creating new solutions. Other signs of *reactiveness, but not proactiveness regarding fake news* are as follows: not informing others much about recognised fake news; not giving much effort in analysing the purpose of particular context although this content may seek to create political, economic or ideological impact; not sharing the news or content to influence the opinion of others.

It could be stated that such results reveal a limited psychological empowerment of young individuals especially in the areas of understanding of “making a difference” with particular actions (such as warning others about harmful information) and seeing the value in implementing particular tasks i.e. being active participants in MIL field (Llorente-Alonso, García-Ael & Topa, 2023). Such results indicate that quite a big proportion of the respondents don’t look like change agents to influence changes in the external environment, including ESG outcomes, because having competence to recognise positive and negative aspects (for example, waste management, community engagement, quality of corporate governance, etc.) itself doesn’t create the desired changes. On the contrary, digital resilience is about how to promote ESG reforms proactively even in the face of adverse circumstances because digital resilience is explained through possessing digital skills, the self-efficacy with technology, and being able to effectively give and receive support (Lee & Hancock, 2023). It is obvious that a basic checking of news and sharing it with the peers for fun is not about digital resilience. Digitally resilient individuals are not stepping back but employ all digital competence to face and adapt the circumstances.

The reactiveness regarding behaviour in media platforms requires MIL education. The limitations of psychological empowerment to become digitally resilient may be reduced by structural empowerment ((Sun, Zhang & Chen, 2012), and we state that MIL education could be as one of the most significant tools to empower individuals. MIL education could be implemented at individual and systemic levels. *Individual level* is related to self-education and training of critical thinking, while *systemic level* is related to educational programs at state level and training systems in the business organisations. Scientific literature emphasises that the approach of a dynamic MIL education should be employed because it is not about reactive tools, such as fact-checking and verification tools, but, on the

contrary, helps to facilitate resilient media engagement among young people (McDougall, 2019; Wardle & Derekhsan, 2017). It is also advisable to combine the training of MIL with cultural studies, to develop critical thinking.

Since young people are very community oriented, it would be necessary to develop MIL programmes in education sector, involving the peers (Gherguț-Babii, Poleac & Obadă, 2025). The latter statement reflects Gen Z social characteristics in fact checking with their peers, which could be strengthened by forming peer networks for collaborative learning and enabling peer-to-peer support within online communities (Hassoun et al., 2025).

5 Conclusions

Media and information literacy (MIL) is an essential competence of a complex and multifaceted nature that can enable Generation Z to critically evaluate information, reducing the risk of disorder of information and protecting their psychological well-being in order to increase digital resilience and thus to empower individuals to effectively impact the functioning of ESG systems for a long term. Thus, MIL should not be viewed merely a cognitive skill but a structural mechanism, which enables Gen Z to influence ESG outcomes. However, it is emphasised that only digitally resilient individuals could impact ESG outcomes because they behave proactively, not reactively. We state that digital resilience is formed through psychological empowerment (meaning, competence, self-determination and impact) and structural empowerment (providing all the necessary tools for performing particular actions). However, Gen Z tends to be passively reactive as the organisations / institutions aiding them don't actively promote them to be proactive and thus structurally don't empower them with essential digital skills and tools.

Empirical research, which was oriented into two age groups (16-19 years old and 20-24 years old) of Gen Z, to test their vulnerability regarding fake news and their MIL skills, revealed that their MIL skills are moderate with a noticeable improvement in the age group of 20-24 years old. However, these skills seem more reactive than proactive – the respondents mostly recognise fake content but not intend to inform others about it or simply scroll down or interact with peers without analysing the aim or purpose of particular content. Thus, such Gen Z individuals don't seem much empowered to enhance ESG outcomes because these require proactive actions.

Since the empirical research was exploratory, further research with an increased scope is required. Because of a limited number of respondents, it was challenging to establish the connection between different items, such as gender or educational institution type. In addition, the empirical research results present the current status of MIL but don't reveal the empowerment phenomenon and strong connections with ESG outcomes.

Thus, future empirical research could be performed by employing a qualitative and quantitative research methodology, which could reveal the complex phenomenon of MIL, digital resilience, ESG outcomes and interrelations among them. Future empirical research could help to answer the following questions: 1) how does wider (political, economic, socio-cultural, technological, ecological, legal) environment *structurally* influence the enhancement of meaning, competence, self-determination and impact of Gen Z regarding MIL and digital resilience? 2) how does MIL and digital resilience are related through *psychological empowerment*? 3) What are the revelations of ESG outcomes, which could be enhanced through the employment of MIL?

In the case of quantitative research approaches, additional scales could be used such as Moral Disengagement Scale (Paciello et al., 2008) or Scale Values in Action, with special emphasis on critical thinking (Park & Peterson, 2006).

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ARTIFICIAL INTELLIGENCE IN MARKETING: A BIBLIOMETRIC MAPPING OF CENTRAL AND EASTERN EUROPEAN RESEARCH

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The increasing adoption of artificial intelligence (AI) in marketing poses significant managerial and governance challenges, particularly for small and medium-sized enterprises (SMEs) operating in dynamic, digitally transforming markets. Although the academic literature on AI in marketing has expanded rapidly since 2020, the thematic structure of this research in the Central and Eastern European (CEE) context remains underexplored. This study aims to map AI-related marketing research in CEE countries. Keyword co-occurrence analysis and network visualisation were conducted using VOSviewer to identify dominant research themes, thematic interconnections, and emerging directions. The findings reveal interconnected thematic clusters addressing AI applications in marketing. The results highlight patterns in how AI-driven marketing and consumer trust are conceptualised in the CEE region. By offering a structured overview of the literature, this study supports a deeper understanding of AI-enabled marketing from a management perspective and provides a foundation for future research on AI adoption among SMEs.

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1 Theoretical background

Artificial intelligence (AI) has rapidly evolved from a technological novelty to a transformative force in marketing strategy and practice. AI-based tools such as machine learning algorithms, natural language processing, and predictive analytics are increasingly shaping customer targeting, personalisation, content generation, and decision support systems. (Davenport et al., 2020; Huang & Rust, 2021) As marketing becomes more data-intensive and automated, companies are increasingly relying on AI to optimise operational efficiency, improve customer engagement, and enhance strategic responsiveness. (Wedel & Kannan, 2016)

The spread of AI in marketing is particularly important for small and medium-sized enterprises (SMEs). SMEs operate within resource constraints, yet face strong pressure to remain competitive. (European Commission, 2023) AI-based marketing tools promise better customer insights, greater cost efficiency, and scalability, reducing the structural disadvantages associated with company size. (Chatterjee et al., 2021) However, the adoption of AI in SMEs is determined by organisational readiness, managerial capabilities, and the institutional environment, which vary significantly across regions. (El-Haddadeh, 2019; Hoffmann & Nurski, 2021)

Beyond the benefits, AI-based marketing also poses challenges for companies. Issues of transparency, explainability, algorithmic bias, and consumer trust have become central problems in the introduction of AI. (Buhmann & Fieseler, 2022; Martin, 2018) As automated decision-making systems increasingly impact consumer behaviour, trust is not only an ethical consideration but also a strategic asset. (Glikson & Woolley, 2020) For small and medium-sized enterprises, which often lack the appropriate infrastructure, the use of AI can be both a competitive advantage and a management burden.

Although research on the use of artificial intelligence in marketing has been growing rapidly since 2020, regional differences remain underexplored. Central and Eastern Europe (CEE) is a particularly interesting region due to its transitional economic structures, high proportion of SMEs, and ongoing digital transformation. (European Investment Bank, 2023) In the CEE region, marketing effectiveness is also shaped by consumer values and trust. Despite growing interest in AI and digital innovation

in Central and Eastern Europe, AI-related marketing research in the region has not yet been systematically mapped.

Through a systematic literature review of AI-related marketing research, this study contributes to our understanding of how AI, marketing, and entrepreneurship are linked in this regional context. It thus provides a basis for identifying thematic gaps and for future research on the effective adoption of AI by SMEs.

2 Methodology

This study uses a systematic literature review (SLR) to examine the use and application of artificial intelligence (AI) in entrepreneurship and SMEs in Central and Eastern Europe (CEE). The review follows the PRISMA 2020 guidelines to ensure transparency, reproducibility, and methodological rigour.

The research aims to identify studies that focus on the use of AI in the marketing activities of businesses operating in Central and Eastern European countries.

In this study, the definition of Central and Eastern European Countries (CEECs) follows the OECD statistical terminology, which identifies CEECs as a group of post-transition European economies, including Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, Estonia, Latvia, and Lithuania. (OECD Glossary; UNESCWA)

2.1 Data source and filtering strategy

The literature review was conducted in the Web of Science database. We used the following search string:

```
("artificial intelligence" OR AI)
AND marketing
AND (use OR application*)
AND (entrepreneur* OR startup* OR "new venture*"
    OR "small business*" OR SME* OR "new firm*"
    OR "entrepreneurial activity"
    OR "family business*" OR "family firm*" OR "family enterprise*"))
```

The search was conducted without geographical restrictions in the initial phase to cover the entire global research area. The initial query yielded 488 records. To ensure transparency and repeatability, only open-access articles were retained. As a result of this narrowing, 241 records remained. To focus on the latest developments in AI applications, we considered only publications from 2020 to 2025. After applying this criterion, 221 records remained. The analysis was limited to the following Web of Science categories:

- Economics
- Business
- Management
- Social Sciences Interdisciplinary

After filtering, 101 studies remained. Finally, a regional filter was applied to select CEE countries. After this filtering stage, 21 articles were identified as potentially relevant. The full texts of the 21 articles were examined to check the following:

1. Location of the empirical sample
2. Expressed relevance to CEE countries
3. AI-related application in a marketing, SME, or entrepreneurial context

At this stage, three articles had to be excluded because their empirical samples were not or only partially conducted in CEE countries: The final sample consisted of 18 empirical studies.

2.2 Characteristics of the final sample

The empirical analysis in this study examines companies operating in the following CEE countries:

- Poland
- Czech Republic
- Hungary
- Slovakia
- Romania

Most of the studies focused on the Visegrad countries (Poland, the Czech Republic, Hungary, and Slovakia). We did not find any empirical studies for Croatia, Bulgaria, Lithuania, Latvia, Estonia, Slovenia, or Albania. This points to a regional imbalance in the Central and Eastern European research environment.

The analysis was followed by a thematic clustering approach, which enabled us to identify the region's main research directions and gaps.

The systematic screening process is summarised in Table 1.

Table 1: Systematic screening process

	Number of studies
Identified records	488
Open access filter	241
Time restriction (2020–2025)	221
Subject category filter	101
Geographical filter	21
Full text exclusions	3
Final studies included	18

Source: www.um.si

Several limitations had to be taken into account during our analysis. The search was limited to the Web of Science database, so relevant studies, indexed elsewhere, may have been omitted. Restrictions on open access may have reduced the total sample size. Geographic filtering was based on country references that appeared in the title, abstract, or full text. As a result, European datasets covering multiple countries without clear regional references may have been omitted.

Despite these limitations, the applied procedure ensures methodological transparency and provides a high-quality collection for the analysis of AI literature used in the marketing of SMEs in Central and Eastern Europe.

3 Results

Before presenting the co-occurrence network of keywords, a descriptive overview of the studies provides insight into the structural characteristics of AI-related marketing research conducted in the CEE context.

The topics that emerge mainly focus on business ($n = 12$) and management ($n = 9$), followed by economics ($n = 6$). Only a few publications represent interdisciplinary social sciences ($n = 2$), while educational research, engineering sciences, and interdisciplinary applications of computer science each have a single publication. This may be due to the selected VoS categories (Figure 1).

This distribution suggests that in the CEE region, artificial intelligence applied in marketing is framed within the selected scientific field category as a management and strategic phenomenon rather than as a technological or IT research area. Discussions related to artificial intelligence are closely linked to corporate performance, innovation, and strategic management frameworks.

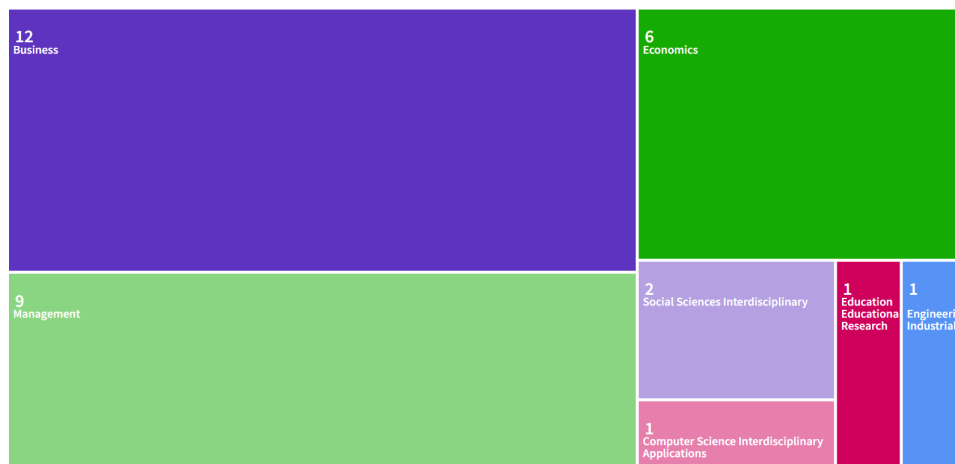


Figure 1: WoS categories TreeMap Chart

Source: own.

Based on geographical distribution, Poland ($n = 5$) and Slovakia ($n = 5$) are the most represented countries, followed by the Czech Republic ($n = 3$) and Romania ($n = 3$). Hungary is represented by only 2 articles ($n = 2$).

It is worth noting that several non-Central and Eastern European countries are also represented (e.g., Spain, England, France, and Malaysia), which reflects patterns of international cooperation in the hit list rather than an empirical focus outside the region (Figure 2).



Figure 2: Countries/Region TreeMap Chart

Source: own.

The results show a concentration in Visegrad countries. This suggests that AI marketing research in Central and Eastern Europe is unevenly distributed, with most work conducted by a limited group of countries. This is more of a regional concentration than widespread research at the Central and Eastern European level.

The publication trend is clearly on the rise. After minimal activity in 2020–2021, the number of studies has been growing steadily since 2022, yet only nine studies on this topic were published last year (Figure 3).

The rapid growth can be explained, on the one hand, by the acceleration of digital development after COVID. Other reasons may include the growing political emphasis on AI adoption in Europe, increased scientific interest in AI-based marketing, and the competitiveness of SMEs. The increase over time suggests that AI in marketing is an emerging trend in the Central and Eastern European scientific environment.

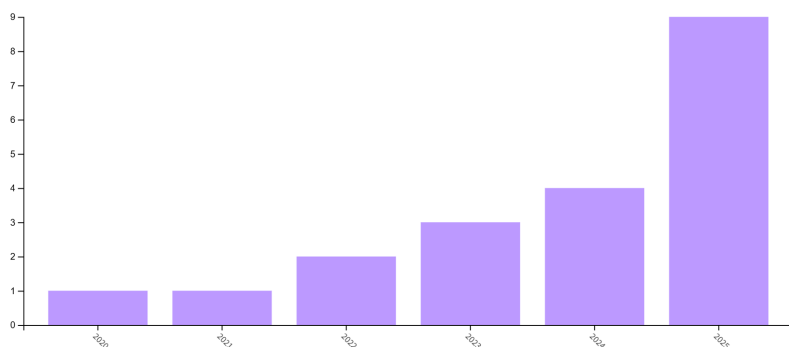


Figure 3: Final publication year Bar Chart

Source: own.

his sample characterisation provides a basis for interpreting the thematic clusters identified in the subsequent keyword co-occurrence analysis.

3.1 Keyword co-occurrence network

A co-occurrence analysis of keywords from the 18 selected studies reveals a thematically differentiated research environment in Central and Eastern Europe. The network visualisation identifies four dominant thematic clusters organised around artificial intelligence as a central node.

Artificial intelligence appears in the network as a central connecting concept, closely linked to management, innovation, SMEs, machine learning, and entrepreneurship. This central role suggests that, in the CEE context, artificial intelligence is not treated merely as a technical construct, but also as a management and strategic phenomenon embedded in the discourse on SME competitiveness and innovation.

The strong correlation between AI and management-related terms suggests that research in the region primarily frames AI from the perspective of governance and decision-making.

The VOSviewer clustering algorithm automatically generated four colour-coded clusters. However, the interpretative analysis showed that one cluster functions primarily as a structural hub focused on artificial intelligence, while the other three

represent thematically coherent research areas. Accordingly, we will focus on presenting the three main clusters. (Figure 4)

Cluster 1: Innovation, performance, and strategic management (red/green zone)

One of the dominant cluster groups includes concepts such as innovation, management, model, corporate performance, business model, risk, impact, and challenges. This cluster reflects a strong orientation towards the following:

- AI-driven organisational transformation
- Impacts on performance
- Strategic adaptation
- Risks and implementation challenges

Rather than measuring specific marketing ROI, many studies frame the introduction of AI as part of broader innovation capabilities and strategic renewal. Company-level performance is often analysed in the context of digital transformation and globalisation dynamics.

Cluster 2: Digital marketing and analytics applications (green zone)

This cluster focuses on digital marketing, analytics, machine learning, natural language processing, and big data. Here, AI appears more in operational marketing contexts:

- Customer data analysis
- Content and communication optimisation
- Social media and digital engagement
- Marketing analytics

However, compared to Western European literature, these topics remain more closely related to SMEs and applications rather than to a purely marketing-technology group. This suggests that in Central and Eastern European research, AI-driven marketing is generally embedded in broader digitalisation narratives and is not treated as a separate specialised field.

Cluster 3: Introduction, acceptance, and technological readiness (blue/yellow zone)

This cluster links adoption, technology, user acceptance, and education with entrepreneurial spirit. The following areas are highlighted:

- Technology acceptance models
- Organisational readiness
- Human capital and digital skills
- Capacity constraints of SMEs

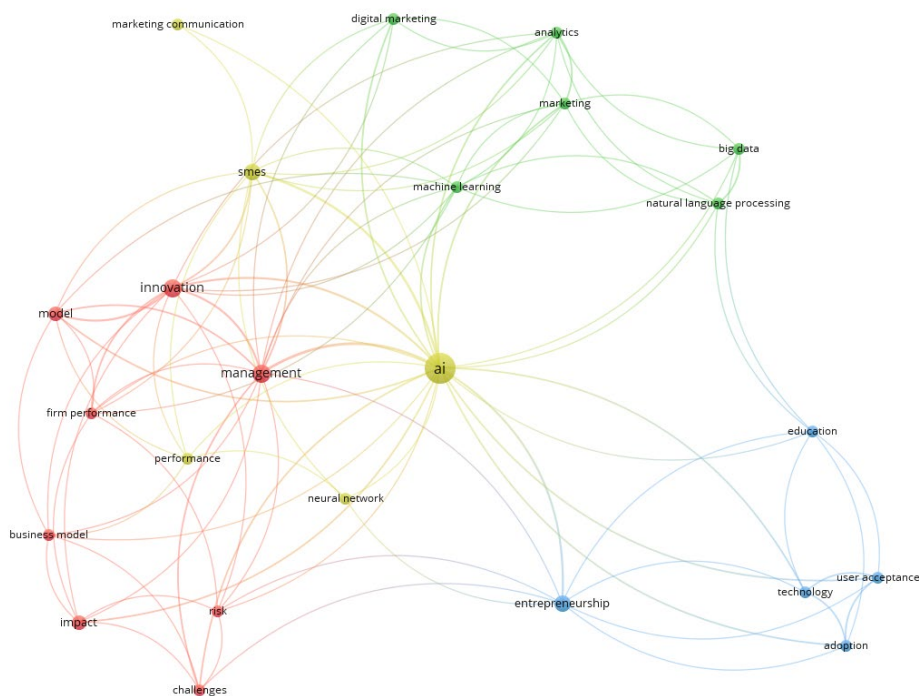


Figure 4: Network visualisation

Source: own.

The overlay visualisation (Figure 5) shows that these application-related topics are gaining prominence in recent publications (2024–2025). Attention is focused on barriers to AI adoption, trust and behavioural factors, risks, challenges, impacts, and user acceptance.

This is particularly relevant for resource-constrained SMEs, where management awareness and user acceptance significantly influence AI adoption. Previous publications (2023) focused on big data, natural language processing, and technical analysis.

This evolution over time indicates the maturity of the research processes:

1. Initially, the focus was on technological capabilities,
2. Then issues of organisational adoption came to the fore,
3. And now the focus is shifting towards governance, accountability, and performance impacts.

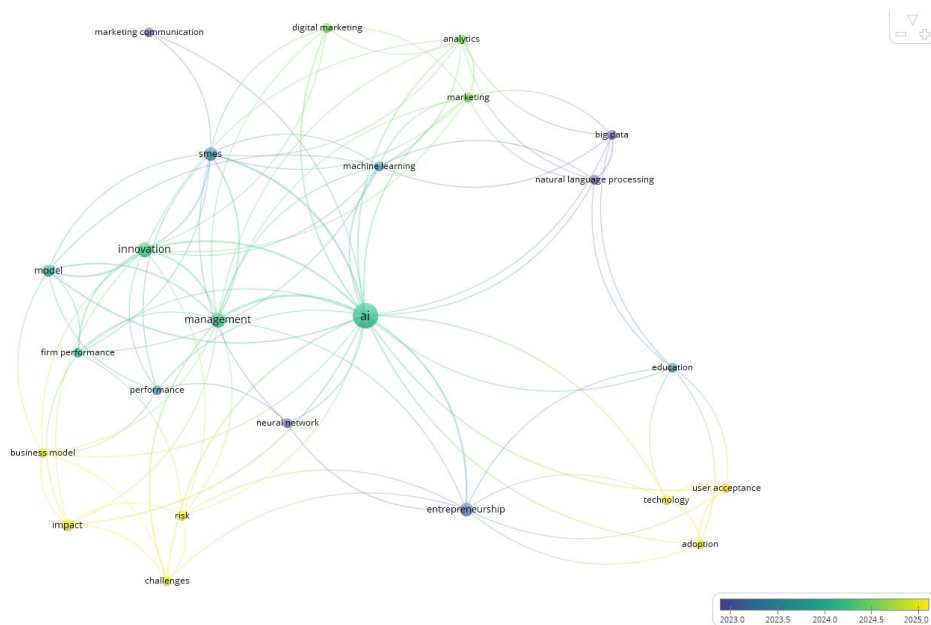


Figure 5: Overlay visualisation

Source: own.

AI-based marketing tools are rarely analysed in isolation. Instead, they are embedded in innovation strategy, application readiness, and executive management context. It is important to note that trust and transparency appear indirectly through concepts such as risk, user acceptance, and challenges, suggesting that governance issues are emerging but have not yet matured enough to form a separate cluster.

Overall, the results show a research environment where AI in marketing is primarily framed as a mechanism for strategic and organisational transformation in SMEs, rather than merely as a technical marketing optimisation tool.

4 Discussion

The bibliometric map provides important insights into how Central and Eastern European (CEE) research defines artificial intelligence (AI) in marketing. The results show that AI-related marketing research in the region is structurally interdisciplinary and closely embedded in the discourse of SMEs and the entrepreneurial sphere.

One of the most striking findings of our study is that AI is not primarily presented as a specific marketing optimisation technology but rather positioned as a broader strategic and innovation-enabling capability. The frequent co-occurrence of AI and terms such as innovation, management, corporate performance, and business model suggests that CEE scholars view the field as part of corporate transformation. In Central and Eastern Europe, AI is part of digitalisation and competitiveness strategies, especially among SMEs, operating under structural constraints. This indicates a management framework in which the introduction of AI is closely linked to long-term survival. This contrasts with some Western literature, where AI is often examined in detail in marketing (e.g., algorithmic targeting, personalised metrics).

In Central and Eastern European marketing, in a small and medium-sized enterprise environment, the examination of AI is characterised by:

- Resource constraints
- Skill gaps
- Institutional transition dynamics
- Pressure for rapid digital transformation

The close relationship between AI, entrepreneurship, and performance reflects the focus of regional research. This is consistent with the general direction of post-socialist economic development in the region, where innovation and internationalisation remain critically important strategies.

Another important contribution of the mapping is the introduction of concepts such as user acceptance, along with the visibility of technology and education. These topics are receiving increasing emphasis in recent publications, suggesting a shift from technological enthusiasm to the realities of implementation.

This evolution reflects the maturity of the research program. Early studies emphasised analytical and technical capabilities (e.g., big data, machine learning), while recent research increasingly examines topics such as organisational readiness, leadership capabilities, and risk perception. This suggests that research in Central and Eastern Europe increasingly recognises the introduction of AI as a socio-technical process rather than merely a technological development. For companies, the introduction of AI is not only a technological innovation but a complex organisational and strategic transformation process that requires the development of new competencies, adaptive operating structures, and management approaches (Koteczki et al, 2025).

Although they do not yet form a separate cluster, governance-related topics appear with keywords such as risk, challenges, and impact. This aligns with growing global concerns about transparency, explainability, and the ethical use of artificial intelligence.

The results suggest that future theoretical developments in the CEE context should integrate a resource-based view (RBV) of AI capability development.

5 Conclusion

Overall, regional research indicates that numerous SMEs face significant challenges in implementing digital transformation initiatives due to insufficient resources.

By identifying thematic clusters and their relationships, this study provides a structured picture of how AI-based marketing is conceptualised in CEE and highlights the need for more performance-oriented, trust-sensitive empirical research.

This study contributes to the literature in three important ways. First, it is the first structured bibliometric map of marketing research on artificial intelligence conducted in the Central and Eastern European (CEE) context, offering a region-specific perspective that has been largely missing from the global discourse. Second, it shows that in CEE marketing research, AI is primarily understood as a strategic and innovation-driven capability in the SME environment, rather than merely as a technical optimisation tool. Third, it identifies a structural gap between application-oriented studies and measurable marketing performance outcomes, underscoring an underexplored area for future empirical research.

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INTERPLAY OF ENDOGENOUS RESOURCES AND EXOGENOUS FORCES IN DRIVING STRATEGIC AGILITY: A MIXED-METHODS STUDY

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Contemporary business environments are characterized by increasing complexity and rapid change, positioning strategic agility as a critical driver of organizational resilience and sustainable success. Study examines strategic agility through an integrative endogenous–exogenous analytical lens, offering a theoretically grounded and empirically robust investigation of how leaders navigate complexity by aligning internal capabilities with external environmental dynamics. Employing a mixed-methods design, study draws on evidence from 100 case studies and integrates quantitative metrics with qualitative insights through the Delphi method, enabling a systematic exploration. This approach facilitates in-depth examination of the interplay between firm-level resources, environmental pressures, and strategic decision-making. Findings indicate that leaders systematically engages endogenous–exogenous (Endo–Exo) analysis exhibit an enhanced capacity to anticipate change, leverage competitive advantages, and foster adaptive organizational cultures. Results further demonstrate a strong association between Endo–Exo analysis and improved strategic coherence, organizational agility, and leadership effectiveness. Research contributes a robust analytical framework for strategic leadership that is both theoretically rigorous and practically relevant within dynamic and uncertain organizational contexts.

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1 Introduction

The contemporary business landscape is increasingly shaped by volatility, uncertainty, complexity, and ambiguity, compelling organizations to continuously reassess how they formulate and implement strategy. Rapid technological advancements, the intensification of global competition, regulatory pressures, and shifting stakeholder expectations have transformed strategic agility from a desirable capability into a fundamental organizational necessity. In this context, strategic agility refers to an organization's ability to sense changes in the environment, rapidly reconfigure resources, and respond effectively through timely and coherent strategic actions. Despite the significant growth of the literature on strategic agility, much of the existing research tends to examine internal organizational capabilities or external environmental forces in isolation. This fragmented perspective limits a comprehensive understanding of how strategic agility is actually developed and sustained in practice.

Organizations do not operate as closed systems; rather, they are embedded in dynamic and fluid environments where endogenous resources – such as leadership competencies, organizational culture, knowledge assets, and structural flexibility – continuously interact with exogenous forces, including market turbulence, technological change, competitive intensity, and institutional constraints. Understanding strategic agility, therefore, requires an integrative analytical approach capable of capturing this interactive dynamic between internal and external factors. Based on this perspective, the article seeks to introduce a novel empirical approach that can generate meaningful results and theoretical novelties in the application of Endo–Exo analysis through advanced mathematical and computational calculations. This approach is expected to provide a new and highly relevant contribution with practical implications for managers and organizational leaders. Building upon this premise, the present study adopts an endogenous–exogenous (Endo–Exo) analytical perspective to examine strategic agility as an outcome of the alignment between internal organizational resources and external environmental conditions. By integrating insights from strategic management, the Resource-Based View, and perspectives from Contingency Theory, the study advances a more holistic framework for analyzing how organizations navigate conditions of complexity and uncertainty. This approach recognizes that strategic agility is not merely the result of possessing superior resources or accurately interpreting external signals; rather, it

emerges from the effective orchestration and prioritization of these factors within strategic decision-making processes. From a methodological standpoint, this research adopts a mixed-methods design in order to ensure both analytical rigor and contextual depth.

Qualitative insights are generated through the Delphi Method, relying on expert evaluations to identify, refine, and validate the key endogenous and exogenous criteria that influence strategic agility. These insights are subsequently operationalized within a quantitative decision-making framework using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The application of TOPSIS enables a systematic multi-criteria evaluation of strategic alternatives, simultaneously considering multiple – often competing – internal and external factors. The integration of TOPSIS into the research design represents a significant methodological contribution. By transforming complex qualitative judgments into measurable criteria and weights, TOPSIS facilitates the ranking of strategic configurations based on their relative proximity to an ideal decision of strategic agility. This approach enhances transparency, reduces subjectivity in strategic evaluation, and provides a powerful decision-support tool for leaders operating in turbulent environments. Furthermore, this approach enables the empirical examination of how different combinations of endogenous resources and exogenous forces influence strategic agility outcomes across diverse organizational contexts.

Based on evidence derived from 100 case studies, the findings indicate that organizations that systematically apply Endo–Exo analysis and multi-criteria decision-making tools, such as the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), demonstrate higher levels of strategic coherence, adaptability, and leadership effectiveness. Leaders who successfully balance internal capabilities with external demands are better positioned to anticipate change, capitalize on competitive opportunities, and cultivate adaptive organizational cultures.

2 Literature review

Strategic agility has been widely recognized in the contemporary strategic management literature as a key organizational capability for coping with environments characterized by uncertainty, rapid change, and high complexity (Doz & Kosonen, 2010; Teece, Peteraf, & Leih, 2016; Clauss et al., 2021). Numerous scholars define strategic agility as the capacity of organizations to sense signals of change, reconfigure resources, and undertake timely strategic actions while maintaining coherence between long-term objectives and short-term decisions (Teece, 2018). However, although the importance of strategic agility is widely acknowledged, the manner in which this concept is operationalized and empirically measured remains fragmented and somewhat ambiguous (Junni et al., 2015; Sampath & Krishnamoorthy, 2022). A dominant stream of the literature focuses on the analysis of organizations' endogenous resources, largely grounded in the resource-based view and capability-based perspectives (Barney, 1991; Elezaj & Kuqi, 2021). These studies emphasize the role of strategic leadership, organizational culture, structural flexibility, human capital, and dynamic capabilities as key determinants of strategic agility (Shin et al., 2015). According to this perspective, organizations that possess unique and difficult-to-imitate resources are better able to adapt and sustain competitive advantage. Nevertheless, this strong emphasis on internal factors often treats organizational resources as relatively static elements detached from the environmental context, thereby underestimating the fact that their value and effectiveness depend significantly on the external conditions in which the organization operates (Eisenhardt & Martin, 2000).

On the other hand, the literature that analyzes exogenous forces focuses on the influence of market volatility, competitive intensity, technological developments, and institutional pressures on the strategic behavior of organizations (Volberda et al., 2021; Wamba et al., 2017). These studies argue that more dynamic and unpredictable environments require higher levels of flexibility and rapid strategic responsiveness (Bettis et al., 2016). However, this line of research also remains largely descriptive and fragmented, as environmental factors are often analyzed as external variables of influence rather than as integral components of a structured decision-making process closely linked to the internal resources of the organization (Adner & Helfat, 2003). As a result, the existing literature is characterized by a clear separation between endogenous and exogenous analyses, creating a significant

theoretical gap in understanding strategic agility as an interactive and dynamic phenomenon. An integrative approach that treats strategic agility as the product of the continuous interaction between internal capabilities and external forces is still largely absent. Furthermore, most studies rely on traditional statistical methods or conceptual analyses, which often fail to capture the multi-criteria complexity of strategic decision-making under conditions of uncertainty. Another important gap relates to the limited application of Multi-Criteria Decision Making (MCDM) methods in the study of strategic agility. Strategic decision-making simultaneously involves multiple—often conflicting—factors that cannot be adequately evaluated through linear or unidimensional approaches (Kahraman et al., 2015; Greco et al., 2016).

Although methods such as the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) have been widely applied in other fields of management and engineering (Behzadian et al., 2012; Hwang & Yoon, 1981), their application in the analysis of strategic agility remains limited in the international literature and is practically unexplored in the context of developing economies, including Kosovo.

This theoretical and methodological gap is further deepened by the scarcity of empirical studies addressing strategic agility within institutional and economic contexts characterized by transition, structural uncertainty, and resource constraints. The dominant literature remains primarily focused on developed economies, leaving the organizational realities of the Western Balkan countries underrepresented (Meyer & Peng, 2016), where the interaction between environmental pressures and internal capabilities is particularly critical (Peng et al., 2017). The contemporary scholarly background on strategic agility suggests that organizational performance and adaptive capacity largely depend on how effectively organizations balance internal resources with the pressures of the external environment (Elezaj & Kuqi, 2023; Elezaj, 2025).

However, most existing studies treat this relationship in a linear or fragmented manner, analyzing either endogenous or exogenous factors without offering analytical mechanisms that explain how these factors interact within the actual process of strategic decision-making (Krasniqi & Elezaj, 2023). The empirical results of the present study directly contribute to addressing this gap by providing structured evidence that strategic agility is the product of a multi-criteria

configuration rather than a single dominant factor (Birkinshaw, Zimmermann & Raisch, 2016; Chen, Neubaum, Reilly & Lynn, 2015). The findings indicate that the strategic alternatives achieving the highest rankings according to the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method are those that demonstrate strong coherence between internal organizational strengths and the systematic exploitation of environmental opportunities, while effectively managing weaknesses and risks. This evidence supports the literature arguing that internal resources are necessary but not sufficient for achieving strategic agility, thereby challenging the implicitly endogenous assumptions of the traditional Resource-Based View. At the same time, the results of the study reveal that environmental pressures, when treated independently, do not generate strategic agility in the absence of internal capabilities capable of absorbing and transforming them into effective strategic actions (Elezaj, Sejdija, & Kuqi, 2023).

From a theoretical perspective, these findings address an important gap in the literature: the lack of empirical operationalization of the Endo–Exo interaction. Unlike previous studies that treat this interaction conceptually or descriptively, this research materializes it through a multi-criteria model in which each dimension of SWOT Analysis contributes measurably to the final outcome of strategic decision-making (Elezaj & Kuqi, 2023). The results demonstrate that no single dimension (strengths, weaknesses, opportunities, or threats) is determinative in isolation; rather, their importance depends on their relative configuration and the strategic weight they assume in relation to one another. From a methodological perspective, the empirical evidence derived through the application of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) directly addresses another prominent gap in the literature, namely the lack of analytical tools for multidimensional strategic decision-making. The results demonstrate that the use of TOPSIS enables the identification of strategic alternatives that are closest to the ideal solution, while simultaneously considering both stimulating and constraining criteria.

This approach overcomes the limitations of traditional statistical methods, which typically analyze isolated relationships between variables without providing a clear and actionable ranking for decision-making purposes. The empirical contribution of the study lies in the fact that the results are generated from an organizational context characterized by structural uncertainty, resource constraints, and evolving

institutional dynamics. Existing literature reveals a notable lack of evidence from transition economies, where exogenous pressures are often stronger and less predictable (Puffer, McCarthy, & Boisot, 2019). The findings of this study indicate that in such contexts, strategic agility does not manifest through spontaneous reactions but rather through structured and analytical decision-making processes that systematically integrate internal and external factors. At the conceptual level, the study advances a novel theoretical conclusion: strategic agility should be conceptualized as the outcome of relative proximity to an ideal strategic configuration rather than as an absolute organizational state.

This conclusion follows directly from the logic of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and represents a significant advancement in the literature by shifting the focus from static measurement of capabilities toward the dynamic assessment of strategic alternatives (Zavadskas, Turskis, Antucheviciene & Zakarevicius, 2012; Mardani, Zavadskas, Khalifah, Jusoh & Nor, 2016; Wang, Wang & Huang, 2019). These findings not only advance the theoretical understanding of strategic agility but also provide clear practical implications for leaders, enabling them to identify optimal strategic decisions in a reasoned, transparent, and empirically supported manner. This methodological integration represents a notable innovation, as it allows for the empirical operationalization of strategic agility as a decision-making process rather than merely a theoretical construct. The study contributes both to the theoretical advancement of understanding strategic agility as an interactive phenomenon and to offering a practical tool for organizational leaders. The application of TOPSIS enables leaders to make more objective decisions, reduce subjectivity, balance internal and external factors, and identify strategic alternatives that are closest to the ideal solution. In this way, the study helps to close existing gaps in the literature and offers an innovative approach suitable for dynamic and unstable contexts, such as that of Kosovo, positioning strategic agility as a measurable, manageable capability grounded in analytical decision-making.

3 Methodology

The study is based on a mixed-methods research design, which combines qualitative inquiry with multi-criteria quantitative analysis, aiming to capture the complexity that characterizes strategic agility and strategic decision-making in fluid environments.

The empirical investigation encompassed 100 case studies, built on semi-structured interviews conducted with senior managers of organizations operating across various sectors in Kosovo. Data collection was carried out through open-ended interview questions, allowing for the elicitation of in-depth assessments regarding internal organizational conditions and external environmental dynamics. To ensure analytical consistency and enable quantitative treatment of the data, qualitative responses were calibrated using a four-point ordinal scale. For the stimulating variables—namely strengths and opportunities—a coding scheme from 1 to 4 was applied, where 1 represents a low impact and 4 indicates a superior level of influence. Conversely, for constraining variables—namely weaknesses and threats—an inverse coding was used, where 1 indicates a high level of negative impact and 4 represents a low level of risk or weakness. This coding system ensures conceptual harmonization across all dimensions and facilitates multi-criteria comparison.

Strategic agility was operationalized through the four dimensions of SWOT analysis: strengths, weaknesses, opportunities, and threats. Each dimension comprises eight empirically identified and validated variables, resulting in a total of 32 variables integrated into the coding and analysis process. These variables were selected based on their theoretical and contextual relevance, reflecting the organizational and institutional realities of Kosovo. Following the coding and normalization of the data, the study applies the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) as the primary analytical tool for deriving results. TOPSIS is used to transform multidimensional assessments into a structured decision-making model, enabling the ranking of strategic alternatives according to their proximity to the ideal solution. This method is particularly suitable for the study, as it allows for the simultaneous evaluation of multiple, often conflicting criteria while maintaining transparency and methodological rigor. Within the TOPSIS model, six strategic alternatives were constructed, representing different decision options for organizational leaders. These alternatives were evaluated against the 32 variables derived from the SWOT analysis, with each criterion assigned a corresponding weight based on strategic importance determined through expert assessments and empirical evidence (*see table 1*).

Table 1: Preview of SWOT axis with coded variables divided in Endo-Exo analysis

Endogenous	Axis	Variable	Coding	Exogenous	Axis	Variable	Coding
	S	Capital circle	x1		W	Exportation	x9
		Increasing investments	x2			Skills and competence	x10
		Possibility of growth	x3			Innovation	x11
		Extend in markets	x4			Market penetration	x12
		Infrastructure	x5			Profitable industry	x13
		Profitability	x6			Technology	x14
		Quality	x7			Limited investments	x15
		Concentration	x8			Financing	x16
	O	Systematic growth	x17		T	Rivalry	x25
		Quality in improving	x18			Taxation	x26
		Focused in innovation	x19			Informal economy	x27
		Penetration in broad markets	x20			Unstable environment	x28
		Motivation of staff	x21			Laws in force	x29
		Consultancy	x22			Staff migration	x30
		Employees education	x23			Income taxes	x31
		Investments in targets	x24			Crisis	x32

Source: author's own work

The analysis was conducted following the standard steps of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodology, including the construction of the decision matrix, its normalization, application of weights, identification of positive and negative ideal solutions, calculation of separation distances, and computation of relative closeness coefficients. This model reflects an optimal balance between leveraging internal strengths, minimizing weaknesses, capitalizing on environmental opportunities, and managing external threats. In this way, the proposed methodology enables the derivation of clear, concise, and empirically grounded decisions, providing an advanced decision-support tool for leaders operating under conditions of complexity and uncertainty. The methodological framework and analytical procedure for integrating SWOT analysis into TOPSIS is realized through a structured operationalization process, which transforms traditional strategic analysis from a primarily descriptive approach into a formal, multi-criteria decision-making model.

In this study, SWOT is not treated merely as a diagnostic tool but as an analytical framework that provides the foundational criteria for the mathematical modeling of strategic alternatives within the TOPSIS framework. Each dimension represents a set of strategic criteria, with strengths and weaknesses reflecting the organization's endogenous factors, while opportunities and threats represent exogenous environmental factors. After completing the coding phase, the initial decision matrix is constructed, where the rows represent the strategic alternatives (the six decision options) and the columns represent the 32 SWOT criteria. Each element of the matrix reflects the assessment of a specific alternative against a given criterion, based on the average or aggregated evaluations obtained from the 100 case studies. The next step involves normalizing the decision matrix to eliminate the effects of differing measurement units and ensure comparability across criteria. This step guarantees that all criteria are expressed on a common scale. Following normalization, the weighted decision matrix is applied. Each criterion is assigned a weight reflecting its relative strategic importance, derived from expert evaluations and the consensus reached through the research process. The normalized values are multiplied by their respective weights to produce the weighted matrix, which represents the actual influence of each criterion on decision-making. Subsequently, the positive ideal solution and the negative ideal solution are determined.

The positive ideal solution represents the most favorable combination of values across all criteria, while the negative ideal solution represents the least favorable combination. For stimulating criteria, the positive ideal solution is identified as the maximum value, whereas for constraining criteria it is the minimum value, reflecting the strategic logic of integrating SWOT within the TOPSIS framework. Next, the separation distances of each alternative from both the positive and negative ideal solutions are calculated, typically using the Euclidean distance metric. These distances measure how close or far each strategic alternative is from the ideal and non-ideal configurations. In the final stage, the relative closeness coefficient for each alternative is computed, expressing the ratio between the distance from the negative ideal solution and the sum of distances from both ideal solutions. The final TOPSIS outcome is the ranking of strategic alternatives based on this relative closeness coefficient, where the alternative with the highest value is considered closest to the strategic ideal. In the context of this study, this top-ranked alternative represents the optimal decision-making model, achieving the best balance between leveraging internal strengths, minimizing weaknesses, capitalizing on opportunities, and

managing external threats. The integration of SWOT into TOPSIS enables an advanced analytical approach, where strategic diagnosis and multi-criteria decision-making interact within a single coherent model. This process enhances the scientific rigor of the analysis while also providing a practical and actionable tool for organizational leaders, guiding them toward clear, structured, and empirically supported strategic decisions.

4 Results and Discussions

The initial matrix contains six decision alternatives (Decision 1 – Decision 6), evaluated across eight criteria (X1–X8). The evaluations are provided on a numerical scale (e.g., 1–5), reflecting the experts’ perceptions of each alternative’s performance against each criterion.

$$w'_i = \frac{w_i}{\sum_i^n w_i} \quad (1)$$

$$\sum_i^n w'_i = 1 \quad (2)$$

Table 2: Variables framework and coding process

	Endogenous																Exogenous															
	s (X1...X8)								w (X1...X8)								o (X1...X8)								t (X1...X8)							
	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8
Decision 1 <i>Expansion into international markets</i>	3	3	2	2	4	3	3	2	2	2	1	2	2	1	2	1	2	3	2	4	2	3	3	3	3	2	2	2	3	4	2	1
Decision 2 <i>Innovation and product differentiation</i>	3	3	2	2	4	3	3	2	3	2	3	2	3	1	2	3	3	2	3	2	3	2	4	3	2	2	3	2	3	4	2	1
Decision 3 <i>Focus on human capital development</i>	4	3	4	2	2	3	3	2	2	2	3	1	2	2	3	3	3	3	4	2	3	4	3	3	3	2	3	2	2	4	3	1
Decision 4 <i>Technological and digital transformation</i>	3	2	3	3	2	3	4	4	3	2	2	1	3	3	3	2	3	3	2	3	2	2	2	3	3	2	4	3	2	3	2	4
Decision 5 <i>Financial consolidation and risk management</i>	2	3	3	4	3	3	3	2	3	3	2	2	3	2	3	2	2	3	2	1	2	2	3	3	2	2	3	2	2	3	2	3
Decision 6 <i>Market consolidation and operational efficiency</i>	3	4	3	2	2	3	4	3	2	1	2	3	2	3	2	1	3	3	4	3	3	2	3	3	3	2	2	3	2	2	2	3
AVG	3.00	3.00	2.83	2.50	2.83	3.00	3.33	2.50	2.50	2.30	2.17	1.83	2.50	2.00	2.50	2.00	2.67	2.67	3.00	2.17	2.83	2.33	3.00	3.00	2.67	2.00	2.83	2.33	3.33	3.33	2.17	2.17
STDEV	0.63	0.63	0.75	0.84	0.98	0.80	0.52	0.84	0.55	0.63	0.75	0.75	0.55	0.89	0.55	0.89	0.52	0.52	0.89	0.75	0.75	0.82	0.63	0.80	0.52	0.80	0.75	0.52	0.52	0.82	0.81	1.33
WEIGHT	4	4	3	4	3	4	4	3	2	1	1	2	2	1	3	2	3	3	4	2	3	3	4	2	2	2	1	2	3	1	2	2
Character	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Norm. weight	0.05	0.05	0.04	0.05	0.04	0.05	0.04	0.02	0.01	0.01	0.02	0.02	0.01	0.04	0.02	0.04	0.04	0.04	0.05	0.02	0.04	0.04	0.05	0.02	0.02	0.02	0.01	0.02	0.04	0.01	0.02	0.02

Source: author’s own calculation

Table 2 represents the empirical basis of the analysis. The variations in the evaluations indicate that the alternatives do not perform equally across all criteria. Some alternatives exhibit high values in growth and innovation criteria, while others are stronger in stability and operational efficiency. This highlights the need for a multi-criteria approach, as no single alternative dominates across all dimensions.

After normalization, all criterion values are transformed onto a comparable scale. This eliminates the influence of differing measurement units and ensures that no criterion gains an artificial advantage due to its numerical magnitude.

$$x''_{ij} = \frac{x'_{ij}}{\sqrt{\sum_{k=1}^n x'^2_{ik}}}$$

(3)

Table 3. Normalization of the variables

Variable normalization		Endogenous																Exogenous																
		s (X1.....Xn)								w (X1.....Xn)								o (X1.....Xn)								t (X1.....Xn)								
		x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	
Decision 1	Expansion into international markets	0.40	0.40	0.27	0.27	0.53	0.40	0.40	0.40	0.27	0.32	0.32	0.16	0.3	0.32	0.2	0.3	0.2	0.30	0.30	0.45	0.30	0.60	0.30	0.45	0.45	0.45	0.30	0.30	0.30	0.45	0.60	0.30	0.15
Decision 2	Innovation and product differentiation	0.40	0.40	0.27	0.27	0.53	0.40	0.40	0.40	0.27	0.48	0.32	0.48	0.3	0.48	0.2	0.3	0.5	0.45	0.30	0.45	0.30	0.60	0.45	0.30	0.30	0.45	0.30	0.45	0.60	0.30	0.15		
Decision 3	Focus on human capital development	0.53	0.40	0.53	0.27	0.27	0.40	0.40	0.40	0.27	0.32	0.32	0.48	0.2	0.32	0.3	0.5	0.5	0.45	0.45	0.60	0.30	0.45	0.60	0.45	0.45	0.45	0.30	0.45	0.30	0.30	0.60	0.45	0.15
Decision 4	Technological and digital transformation	0.40	0.27	0.40	0.40	0.27	0.40	0.53	0.53	0.48	0.32	0.32	0.2	0.48	0.5	0.5	0.3	0.45	0.45	0.30	0.45	0.30	0.30	0.30	0.45	0.45	0.30	0.60	0.45	0.30	0.45	0.30	0.60	
Decision 5	Financial consolidation and risk management	0.27	0.40	0.40	0.53	0.40	0.40	0.40	0.27	0.48	0.48	0.32	0.3	0.48	0.3	0.5	0.3	0.30	0.45	0.30	0.15	0.30	0.30	0.45	0.45	0.30	0.30	0.45	0.30	0.30	0.45	0.30	0.45	
Decision 6	Market consolidation and operational efficiency	0.40	0.53	0.40	0.27	0.27	0.40	0.53	0.40	0.32	0.16	0.32	0.5	0.32	0.5	0.3	0.2	0.45	0.45	0.60	0.45	0.45	0.30	0.45	0.45	0.45	0.30	0.30	0.45	0.30	0.30	0.45	0.45	

Source: author's own calculation

Normalization is a critical step, as it ensures objectivity in comparison (*see table 2*). At this stage, it is observed that some alternatives that had high absolute values in the initial matrix lose their relative dominance, while others gain weight. This indicates that relative performance is more important than absolute values in strategic decision-making.

The findings indicate that strategic alternatives performing strongly in opportunity-driven and strength-based criteria gained a competitive advantage, whereas those exposed to high threat or weakness-related criteria experienced a decline in overall ranking. The criteria are then multiplied by their respective weights, reflecting the strategic importance of each criterion in the decision-making process. More critical criteria exert a greater influence on the final outcome.

$$wie_{ij}^m = w'_i * x''_{ij}$$

(4)

Table 4: Weighted diagnostic matrix of variables

Weighted diagnostic matrix of variables		Endogenous																Exogenous															
		s								w								o								t							
		(X1...X8)								(X1...X8)								(X1...X8)								(X1...X8)							
		x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8
Decision 1	Expansion into international markets	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.00	
Decision 2	Innovation and product differentiation	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00
Decision 3	Focus on human capital development	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Decision 4	Technological and digital transformation	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Decision 5	Financial consolidation and risk management	0.01	0.02	0.01	0.03	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Decision 6	Market consolidation and operational efficiency	0.02	0.03	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.03	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01

Source: author's own calculation

This table 4, reflects the organization's strategic priorities. Alternatives that perform well on highly weighted criteria gain a significant advantage, whereas those that are strong only in less important criteria lose position. This stage directly links the numerical analysis to the management's strategic vision and objectives.

$$v_i^+ = \begin{cases} \max_j v_{ij} \\ \min_j v_{ij} \end{cases} \begin{cases} \text{for benefit} \\ \text{for no-benefit} \end{cases}$$

$$v_i^- = \begin{cases} \min_j v_{ij} \\ \max_j v_{ij} \end{cases} \begin{cases} \text{for benefit} \\ \text{for no-benefit} \end{cases} \quad (5)$$

Table 5: Determination of ideal object and ant-ideal object

		Endogenous																Exogenous															
		s								w								o								t							
		(X1...X8)								(X1...X8)								(X1...X8)								(X1...X8)							
		x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8
Decision 1	Expansion into international markets	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.00
Decision 2	Innovation and product differentiation	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00
Decision 3	Focus on human capital development	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
Decision 4	Technological and digital transformation	0.02	0.01	0.01	0.02	0.01	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Decision 5	Financial consolidation and risk management	0.01	0.02	0.01	0.03	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Decision 6	Market consolidation and operational efficiency	0.02	0.03	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.02	0.02	0.03	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.01
	Character	b	b	b	b	b	b	b	b	b	b	b	b	b	b	nb	b	b	b	b	b	b	b	b	b	b	nb	nb	nb	b	nb	b	nb
	d+	0.03	0.03	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.02	0.02	0.03	0.01	0.01	0.00	0.01	0.02	0.00	0.01	0.01	
	d-	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	

Source: author's own calculation

Alternatives that are closer to the positive ideal solution and farther from the negative ideal solution are considered more favorable. This step is essential because it evaluates not only absolute performance but also the relative positioning of alternatives with respect to extreme scenarios (best and worst).

$$[+] = (w_{ij}^m - v_i^+)^2 \quad (6)$$

$$[-] = (w_{ij}^m - v_i^-)^2 \quad (7)$$

The values presented in the table represent the positive ideal distance (d^+) of each decision alternative from the ideal solution. The smaller the d^+ value, the closer the alternative is to the optimal strategic solution, whereas the negative ideal distance values (d^-) indicate that the larger the d^- value, the farther the alternative is from the non-optimal strategic solution.

$$d_j^+ = \sqrt[p]{\sum_{i=1}^m |v_{ij} - v_i^+|^p}, \quad (8)$$

[d+]	Endogenous																Exogenous															
	s								w								o								t							
	(X1.....Xn)								(X1.....Xn)								(X1.....Xn)								(X1.....Xn)							
	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8
Decision 1 <i>Expansion into international markets</i>	0.00004	0.00004	0.00010	0.00017	0.00000	0.00000	0.00004	0.00010	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00003	0.00003	0.00005	0.00001	0.00000	0.00012	0.00005	0.00000	0.00001	0.00000	0.00000	0.00000	0.00003	0.00001	0.00000	0.00000
Decision 2 <i>Innovation and product differentiation</i>	0.00004	0.00004	0.00010	0.00017	0.00000	0.00000	0.00004	0.00010	0.00002	0.00000	0.00002	0.00002	0.00002	0.00000	0.00000	0.00000	0.00003	0.00005	0.00001	0.00003	0.00012	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003	0.00001	0.00000	0.00000
Decision 3 <i>Focus on human capital development</i>	0.00000	0.00004	0.00000	0.00017	0.00010	0.00000	0.00004	0.00010	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00003	0.00000	0.00000	0.00001	0.00003	0.00000	0.00005	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00000
Decision 4 <i>Technological and digital transformation</i>	0.00004	0.00017	0.00002	0.00004	0.00010	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002	0.00002	0.00002	0.00003	0.00002	0.00000	0.00000	0.00012	0.00000	0.00012	0.00012	0.00022	0.00000	0.00001	0.00000	0.00001	0.00001	0.00000	0.00000	0.00000	0.00012
Decision 5 <i>Financial consolidation and risk management</i>	0.00017	0.00004	0.00002	0.00000	0.00002	0.00000	0.00004	0.00010	0.00002	0.00002	0.00000	0.00002	0.00002	0.00000	0.00003	0.00002	0.00003	0.00000	0.00012	0.00005	0.00012	0.00012	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005
Decision 6 <i>Market consolidation and operational efficacy</i>	0.00004	0.00000	0.00002	0.00017	0.00010	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00004	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003	0.00012	0.00005	0.00000	0.00001	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00005

Source: author's own calculation

[d-]	Endogenous																Exogenous															
	s								w								o								t							
	(X1.....Xn)								(X1.....Xn)								(X1.....Xn)								(X1.....Xn)							
	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8	x1	x2	x3	x4	x5	x6	x7	x8
Decision 1 <i>Expansion into international markets</i>	0.00004	0.00004	0.00000	0.00000	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00002	0.00003	0.00000	0.00003	0.00000	0.00005	0.00001	0.00003	0.00000	0.00022	0.00000	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00001	0.00012
Decision 2 <i>Innovation and product differentiation</i>	0.00017	0.00004	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00003	0.00003	0.00012	0.00001	0.00003	0.00012	0.00005	0.00000	0.00000	0.00000	0.00000	0.00001	0.00003	0.00000	0.00000	0.00012
Decision 3 <i>Focus on human capital development</i>	0.00004	0.00000	0.00002	0.00004	0.00000	0.00000	0.00004	0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00003	0.00003	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003	0.00000	0.00001	0.00000
Decision 4 <i>Technological and digital transformation</i>	0.00000	0.00004	0.00002	0.00017	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00005	0.00000	0.00001	0.00000	0.00000	0.00001	0.00003	0.00000	0.00001	0.00001
Decision 5 <i>Financial consolidation and risk management</i>	0.00004	0.00017	0.00002	0.00000	0.00000	0.00000	0.00004	0.00002	0.00002	0.00000	0.00000	0.00002	0.00000	0.00000	0.00003	0.00004	0.00003	0.00003	0.00012	0.00005	0.00003	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000	0.00000	0.00003	0.00001	0.00001	0.00001
Decision 6 <i>Market consolidation and operational efficacy</i>	0.00004	0.00017	0.00002	0.00000	0.00000	0.00000	0.00004	0.00002	0.00002	0.00000	0.00000	0.00002	0.00000	0.00000	0.00003	0.00004	0.00003	0.00003	0.00012	0.00005	0.00003	0.00000	0.00005	0.00000	0.00000	0.00000	0.00001	0.00000	0.00003	0.00001	0.00001	0.00001

Source: author's own calculation

Table 7: Distance from ideal object

Object +		
Decision 1	<i>Expantion into international markets</i>	0.03100
Decision 2	<i>Innovation and product differentiation</i>	0.02811
Decision 3	<i>Focus on human capital development</i>	0.02742
Decision 4	<i>Technological and digital transformation</i>	0.03694
Decision 5	<i>Financial consolidation and risk management</i>	0.03406
Decision 6	<i>Market consolidation and operational efficacy</i>	0.02800

Source: author's own calculation

The results indicate that technological and digital transformation (0.03694) and financial consolidation with risk management (0.03406) represent the most preferred strategic alternatives, reflecting the importance of adaptive capabilities and financial stability in decision-making.

$$d_j^- = \sqrt[p]{\sum_{i=1}^m \left| v_i - v_i^- \right|^p}. \quad (9)$$

Table 8: Distance of anti-ideal object

Object –		
Decision 1	<i>Expantion into international markets</i>	0.04369
Decision 2	<i>Innovation and product differentiation</i>	0.03840
Decision 3	<i>Focus on human capital development</i>	0.03016
Decision 4	<i>Technological and digital transformation</i>	0.03673
Decision 5	<i>Financial consolidation and risk management</i>	0.04180
Decision 6	<i>Market consolidation and operational efficacy</i>	0.02955

Source: author's own calculation

Expantion into international markets (0.04369) and financial consolidation with risk management (0.04180) exhibit the greatest distance, indicating the strongest avoidance of the least favorable scenario.

Table 9: Integration of ideal and anti-ideal object

Object		d+ + d-
Decision 1	<i>Expansion into international markets</i>	0.07469
Decision 2	<i>Innovation and product differentiation</i>	0.06651
Decision 3	<i>Focus on human capital development</i>	0.05759
Decision 4	<i>Technological and digital transformation</i>	0.07368
Decision 5	<i>Financial consolidation and risk management</i>	0.07586
Decision 6	<i>Market consolidation and operational efficacy</i>	0.05756

The values (d⁺ + d⁻) shows that Financial Consolidation and Risk Management (0.07586) achieves the highest performance, demonstrating the greatest proximity to the ideal solution.

This alternative is followed by Expansion into International Markets (0.07469) and Technological and Digital Transformation (0.07368), which also exhibit relatively strong strategic potential. In contrast, Decision 3 and Decision 6 record the lowest values, suggesting a comparatively lower strategic impact when evaluated against the other alternatives.

$$S_j = \frac{d_j^-}{d_j^+ - d_j^-}. \quad (10)$$

The relative closeness coefficient (S_j) was calculated for each alternative, and the final ranking was determined based on these values. The alternative with the highest S_j value is identified as the most suitable strategic option.

Table 10: Construction of the aggregate measure of decisions

Object		S _j	Ranking
Decision 1	<i>Expansion into international markets</i>	0.58496	1
Decision 2	<i>Innovation and product differentiation</i>	0.57741	2
Decision 3	<i>Focus on human capital development</i>	0.52380	4
Decision 4	<i>Technological and digital transformation</i>	0.49859	6
Decision 5	<i>Financial consolidation and risk management</i>	0.55096	3
Decision 6	<i>Market consolidation and operational efficacy</i>	0.51347	5

Source: author's own calculation

The final ranking clearly shows that the best strategic alternative is not necessarily the most aggressive or the most conservative one, but rather the option that achieves an optimal balance among benefits, risks, and organizational capabilities. According to the preliminary ranking results, the alternatives that are most focused and highly ranked in terms of attractiveness and strategic necessity are Decision 1 and Decision 2, followed by Decision 5, Decision 3, Decision 6, with the lowest-ranked option being Decision 4. These rankings were calculated and derived through the relative closeness coefficient S_j . The highest-ranked alternative represents the most balanced strategic option, effectively leveraging organizational strengths and opportunities while minimizing weaknesses and threats. Conversely, lower-ranked alternatives indicate higher exposure to risks or insufficient utilization of internal capabilities.

$$\begin{cases} 1 & \text{for } m_s \in (\bar{m}_{m_{s0}} + \sigma_{m_{s0}}; \infty), \\ 2 & \text{for } m_s \in (\bar{m}_{m_{s0}}; \bar{m}_{m_{s0}} + \sigma_{m_{s0}}), \\ 3 & \text{for } m_s \in (\bar{m}_{m_{s0}} - \sigma_{m_{s0}}; \bar{m}_{m_{s0}}), \\ 4 & \text{for } m_s \in (-\infty; \bar{m}_{m_{s0}} - \sigma_{m_{s0}}). \end{cases} \quad (11)$$

Table 11: Classification of the objects-decisions

Object		S_j	Ranking	Class			
Decision 1	<i>Expantion into international markets</i>	0.58496	1	1			
Decision 2	<i>Innovation and product differentiation</i>	0.57741	2	1			
Decision 3	<i>Focus on human capital development</i>	0.52380	4	3			
Decision 4	<i>Technological and digital transformation</i>	0.49859	6	4			
Decision 5	<i>Financial consolidation and risk management</i>	0.55096	3	2			
Decision 6	<i>Market consolidation and operational efficacy</i>	0.51347	5	3			
	AVG	0.54153					
	STDEV	0.03523	Border			0.57677	
	MEAN+STDEV	0.57677				0.54153	
	MEAN-STDEV	0.50630				0.50630	

Source: author's own calculation

The results demonstrate that the integration of SWOT and TOPSIS provides a robust and systematic framework for strategic decision-making. Unlike traditional SWOT analysis, which is primarily descriptive, the combined approach enables quantitative evaluation and objective comparison of strategic alternatives. The ranking outcomes highlight that strategic success is not solely dependent on

aggressive growth or conservative stability, but rather on achieving an optimal balance between internal capabilities and external environmental conditions. Furthermore, the sensitivity of the results to criterion weighting emphasizes the critical role of managerial judgment in defining strategic priorities (Morina & Elezaj, 2025; Elezaj, Morina & Dreshaj, 2025).

5 Conclusions

The results indicate that the strategic alternatives exhibit different levels of proximity to the ideal solution, reflected by the S_j values and their respective rankings. The alternative Expansion into International Markets ($S_j = 0.58496$) ranks first and demonstrates the highest strategic performance, followed by Innovation and Product Differentiation ($S_j = 0.57741$). These two alternatives belong to Class 1, indicating the highest potential for improving organizational performance. The alternative Financial Consolidation and Risk Management ($S_j = 0.55096$) ranks third and is classified within Class 2, indicating a relatively strong but not optimal level of strategic performance. Meanwhile, Focus on Human Capital Development ($S_j = 0.52380$) and Market Consolidation and Operational Efficiency ($S_j = 0.51347$) fall into Class 3, representing strategies with moderate impact that require further improvements to enhance their effectiveness. Finally, Technological and Digital Transformation ($S_j = 0.49859$) records the lowest value and is classified within Class 4, indicating a relatively low level of alignment with the ideal solution under the current conditions. Furthermore, the statistical thresholds derived from $MEAN \pm STDEV$ establish the classification boundaries used in the table. The upper limit ($MEAN + STDEV = 0.57677$) identifies alternatives with very high performance (Class 1), while the lower limit ($MEAN - STDEV = 0.50630$) separates strategies with lower strategic impact (Class 4). These statistical parameters therefore provide an objective basis for grouping the decision alternatives into different performance classes and for supporting the interpretation of the ranking results.

Class 1: High Priority Decisions – these decisions are strategically the most critical, as evidenced by their highest S_j values (0.58496 and 0.57741). Expanding into international markets represents a major opportunity for growth and exposure to new revenue streams.

At the same time, focusing on innovation and differentiating products ensures the organization stays competitive and relevant in fast-evolving markets. Together, these decisions form the backbone of a forward-looking strategy that emphasizes both growth and uniqueness. The organization should create detailed market entry strategies, including feasibility studies, risk assessments, and adaptation plans for local regulations and customer preferences. Investment in R&D is essential to maintain product innovation. Regular monitoring and flexibility in strategy execution are critical to respond to market feedback. Care must be taken to manage financial exposure and maintain brand integrity while pursuing ambitious growth.

Class 2: Upper-Medium Importance – this decision holds significant importance ($S_i = 0.55096$) as it ensures the financial stability and resilience of the organization. Sound financial management provides the foundation upon which higher-priority strategic moves can be safely executed. Without strong financial control, even the most promising growth strategies may falter. Implement robust internal controls, consolidate financial structures, and maintain continuous monitoring of risk exposure. This decision also involves regularly reviewing financial performance and adapting plans to avoid unnecessary vulnerabilities. Careful attention should be paid to regulatory compliance, transparency, and the balance between risk mitigation and strategic investments.

Class 3: Medium Importance – with S_i values of 0.52380 and 0.51347, these decisions are central for strengthening organizational capacity and operational performance. Investing in human capital ensures the workforce is skilled, motivated, and aligned with strategic goals. Operational improvements and market consolidation enhance efficiency and competitive positioning. While not the very top priority, these decisions are crucial for long-term sustainability. Develop comprehensive training programs and career development initiatives. Optimize operational processes to reduce costs and increase efficiency. Align workforce planning with strategic goals to ensure the right talent is in place. Care should be taken to maintain employee engagement while implementing operational changes to avoid disruption of services or quality.

Class 4: Medium-Low Importance – although lower in priority ($S_i = 0.49859$), technological and digital transformation is still important for future competitiveness. It enhances efficiency, supports innovation, and positions the organization for long-

term adaptability. However, the benefits may take longer to materialize and require careful management to prevent disruption.

Start with pilot projects to test new technologies before scaling organization-wide. Provide training and change management programs to ensure adoption by staff. Continuously monitor technological investments and assess their impact on operational performance. Care should be taken to avoid overcomplicating processes or incurring costs without clear returns.

The ranking and classes suggest a structured approach: prioritize high-impact growth and innovation initiatives (Class 1), ensure strong financial foundations (Class 2), strengthen internal capacity and operational performance (Class 3), and gradually implement technological transformation (Class 4). This phased approach allows the organization to balance ambition with stability, ensuring long-term sustainable development. The integration of SWOT with the TOPSIS method provides a robust analytical approach, enabling not only the selection of the optimal strategy but also the determination of the prioritization and timing of strategy implementation for the future.

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MIXED EMBEDDEDNESS AND INSTITUTIONAL CONSTRAINTS: A BIBLIOMETRIC ANALYSIS OF ETHNIC ENTREPRENEURSHIP (2015–2025)

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As global economies prioritize sustainable governance, rising institutional standards have created a "cost floor" that threatens the survival of ethnic SMEs, particularly within the rigid regulatory landscape of Europe. This study conducts a systematic bibliometric analysis of 492 articles (2015–2025) from the Web of Science to map how academic literature tracks these institutional constraints. The mapping identifies a significant geographical asymmetry, where a dominance of North American studies overlooks the specific structural pressures found in European welfare states. A primary objective is to investigate an identified "theoretical leapfrog" in the field, where research transitions from sociological enclave studies directly to psychological resilience while bypassing the actual mechanics of institutional transition. Finally, by justifying keywords like "Mixed Embeddedness" and "Institutional Constraints," the study identifies a critical gap in regulatory inclusivity and provides a data-driven roadmap for future research into ethnic business survival.

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1 Introduction

As global economies increasingly prioritize sustainable governance, the interplay between rising institutional standards and the survival of ethnic Small and Medium Enterprises (SMEs) has emerged as a critical site of institutional tension. While international frameworks, such as standardized labor codes and safety protocols like HACCP (Hazard Analysis and Critical Control Points) are designed to ensure public welfare (Yapp & Fairman, 2006), their implementation often acts as a double-edged sword. For small ethnic firms, these regulations impose a regulatory cost floor that can unintentionally marginalize traditional, low-margin business models (Smallbone & Welter, 2001; Kloosterman, 2010). This raises an urgent question for both policymakers and researchers about whether modern formalization efforts are fostering economic inclusion or are they just displacing the businesses they meant to regulate (Obschonka et al., 2018). These standards often involve high entry and maintenance costs, disproportionately affecting vulnerable entrepreneurs. This makes it important to assess whether current academic research reflects these changing structural conditions.

Researching this phenomenon within the European context is essential due to the continent's unique and rigid institutional landscape. Unlike the more liberal market economies, where ethnic enclaves often operate with more flexibility, European entrepreneurs have to deal with much more rigid regulations and welfare state requirements. As European cities increasingly adopt "green" and "sustainable" urban policies, they have become a testing ground for whether high-standard governance can really be inclusive. Despite this, there is a perceived geographical asymmetry in existing literature, with a dominance of studies focused on North America and the UK. This geographical gap makes a mapping of the field necessary to see how many studies actually look at these specific European constraints.

The primary objective of this study is to address these gaps by conducting a systematic bibliometric analysis of 492 peer-reviewed articles from the Web of Science spanning 2015 to 2025. The goal is to map the field's intellectual structure and find the main thematic clusters. A central aim is to investigate a 'theoretical leapfrog' in the literature, referring to an imbalance in which sociological perspectives on ethnic enclaves and more recent psychological approaches to entrepreneurial resilience have developed more rapidly than meso-level institutional

analyses. This study intends to quantify the extent of this bypass to determine if the literature has neglected the mid-level regulatory processes that determine business survival. To achieve this, the search strategy utilizes specific keywords such as "Mixed Embeddedness," "Institutional Constraints," and "Regulatory Gentrification." These terms are justified as the necessary analytical pillars for capturing the link between an entrepreneur's social capital and the aggressive formalization required by modern governments.

This study contributes to the literature in three ways. First, it extends the Mixed Embeddedness framework by highlighting the underexplored role of regulatory standardization in shaping entrepreneurial trajectories. Second, it connects this dynamic to Institutional Void Theory by conceptualizing the 'standardization gap' as a lack of intermediary support structures. Third, it identifies a 'theoretical leapfrog' in the literature, pointing to an imbalance between sociological, psychological, and institutional perspectives.

2 Methodology

2.1 Data Collection

Data were retrieved from the Web of Science (WoS) Core Collection, chosen for its peer-reviewed journals and its widespread use in bibliometric research. To ensure a comprehensive overview of the institutional environment, a broad search string was utilized to capture the intersection of migrant business and regulatory constraints: ("*ethnic entrepreneur*" OR "migrant entrepreneur*" OR "immigrant entrepreneur*" OR "immigrant business" OR "minority business" OR "ethnic business") AND ("mixed embeddedness" OR "social capital" OR "institution*" OR "regulation" OR "policy" OR "gentrification" OR "compliance" OR "standard*" OR "informal economy")*. The search was limited to documents published between 2015 and 2025, filtered for English language and restricted to articles, review articles, and early access papers to ensure peer-reviewed quality. This process yielded a final dataset of 492 documents.

2.2 Bibliometric Analysis & Data Processing

Co-occurrence analysis was conducted using VOSviewer (Van Eck & Waltman, 2010). To ensure theoretical clarity, a three-step cleaning protocol was applied to the initial 1,916 unique keywords. First, semantic standardization utilized a custom

thesaurus developed by the authors based on iterative review of keyword variants and domain-specific terminology. This process aimed to consolidate synonymous terms (e.g., ‘immigrant entrepreneur’ and ‘migrant entrepreneur’) while preserving conceptual distinctions where relevant. In some cases, broader umbrella terms were used (e.g., grouping ‘racism’ and ‘inequality’ under ‘discrimination’) to enhance network density. While necessary for network density, we acknowledge that this categorization risks oversimplifying the distinct institutional origins of these barriers. Second, exclusion criteria removed generic search terms such as “immigrant entrepreneurship” and “Business”; and geographical identifiers were also removed to mitigate centrality bias and emphasize universal variables. Finally, a minimum occurrence threshold of 5 was applied to balance network interpretability and inclusiveness, a commonly used approach in bibliometric studies. Following these exclusions, 35 keywords were retained for the final network analysis. The resulting map revealed four distinct theoretical clusters (Institutional, Socio-Spatial, Agency, and Resources), derived through association strength normalization.

3 Findings

3.1 Publication Trends

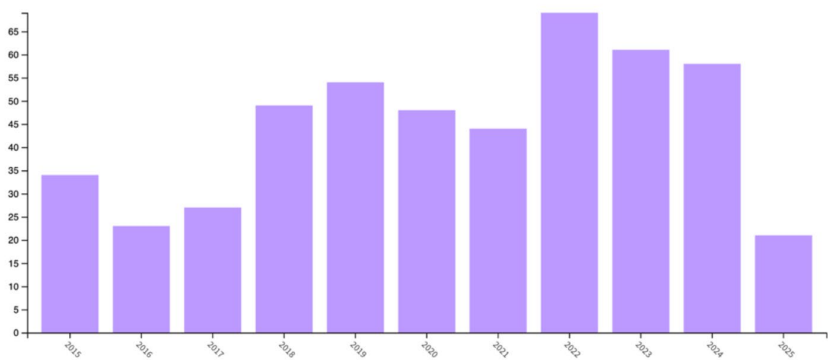


Figure 1: Number of articles by year (2015–2025)
Source: own.

The analysis of publication volume over the last decade reveals a non-linear growth trajectory, reflecting the field’s responsiveness to global structural shocks. The data indicates three distinct phases of academic interest. Firstly, between 2015 and 2019,

the field experienced moderate, organic growth, rising from 34 publications in 2015 to 54 in 2019. This period corresponds to the consolidation of "Mixed Embeddedness" as a dominant theoretical framework, where research focused on the stable integration of immigrant businesses into host economies. A notable contraction occurred in 2021, where output dropped to 44 publications. This decline likely reflects the immediate operational disruptions caused by the COVID-19 pandemic, which temporarily stalled fieldwork and empirical data collection. Following the dip, the field experienced its most significant surge, peaking at 68 publications in 2022 and maintaining high levels through 2023 (61) and 2024 (58). This sharp increase correlates with the emergence of "Resilience" and "Covid-19" as key terms in the yellow cluster (see Figure 3). It suggests a theoretical pivot that scholars moved rapidly to study how ethnic entrepreneurs survived institutional voids during the crisis. This trend indicates that the research focus often jumps straight from culturalist explanations to crisis-oriented coping, largely leapfrogging the steady-state mechanics of institutional standardization. The recorded volume for 2025 (21) is notably lower. However, this figure is a procedural artifact rather than a thematic shift. Because the data collection occurred in early 2026, the 2025 results remain incomplete due to the standard indexing latency of the Web of Science Core Collection.

3.2 Geographic Asymmetry



Figure 2: Number of articles by year (2015–2025).

Source: own.

The analysis of scientific articles by country (Figure 2) reveals a pronounced geographical asymmetry in the literature. The field is overwhelmingly dominated by stable, developed Western economies, with the USA and England collectively accounting for a significant portion of the total output. This is followed by other major countries such as Australia (35) and Canada (37). This focus implies that "Mixed Embeddedness" and other fundamental ideas of ethnic entrepreneurship are highly adapted to the institutional circumstances of developed, liberal market countries. Western Europe also maintains a strong presence, led by Germany (39), Sweden (32), and the Netherlands (27). These nations represent "coordinated market economies" with robust, stable welfare states. The high output from the Netherlands is particularly notable given its size, reflecting the Dutch origins of the Mixed Embeddedness approach (Kloosterman et al.). In stark contrast, representation from Post-Socialist Transition Economies is marginal. Poland (23 documents) is the only Central European nation to appear as a significant node. This gap is particularly critical when considering the Adriatic and Balkan regions (including Slovenia, Croatia, and Serbia), which are notably absent from the bibliometric clusters. While China (40) represents a major non-Western contributor, its unique state-capitalist context differs significantly from the unstable, democratizing institutional settings of Central and Eastern Europe. This geographical skew provides a structural explanation for the "Standardization Gap." Since the vast majority of research originates from countries with mature regulatory frameworks (USA, UK, Germany), existing theories presuppose a baseline of institutional stability. Consequently, the specific challenges of standardizing businesses in volatile, post-socialist environments, where institutions are often "voids" rather than "frameworks"—remain undertheorized because the primary data sources (Western nations) do not exhibit these conditions.

3.3 Intellectual Structure: Cluster Analysis and Network Topology

The Institutional Cluster (Red) functions as the research field's structural backbone, connecting the institutional environment and specific sectors to outcome variables like performance and innovation. A critical pattern within this topology is the peripheral positioning of "informality," which links directly to institutional and transition nodes but lacks any mediating ties to "compliance" or "formalization." This visual gap highlights the 'standardization gap' and is consistent with institutional void theory, suggesting that the absence of intermediary structures

limits the transition from informality to formalization. Furthermore, while bureaucratic rules are shown to dictate business success, they remain largely decoupled from the actual strategic adaptations entrepreneurs utilize to navigate these environments.

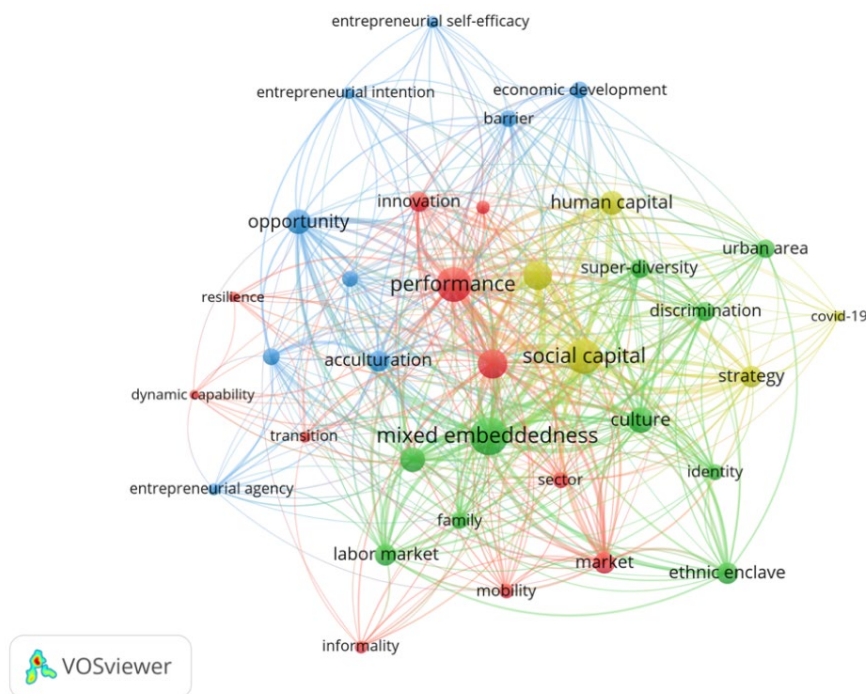


Figure 3: Network Visualization
Source: own.

The second cluster, highlighted in green, defines the socio-spatial location of the entrepreneur through nodes such as mixed embeddedness, urban area, and the ethnic enclave. A significant finding within this cluster is the location of the "labor market" node, which appears within this social grouping rather than the economic one, and is tightly coupled with discrimination and identity. This supports the "Blocked Mobility Hypothesis," indicating that immigrants do not enter the labor market on neutral economic terms; instead, social exclusion pushes them toward self-employment within their own enclaves (Light, 1972). This dynamic forms the foundation of 'Regulatory Gentrification'. As tightening regulations fail to facilitate market integration (Smallbone & Welter, 2001; Kloosterman, 2010), they instead

interact with social barriers and blocked mobility (Light, 1972) to force entrepreneurs deeper into segregated communities for survival (Vertovec, 2007).

The Psychological Cluster (Blue) reveals a significant blind spot where scholars study the intent to start a business in isolation from the bureaucratic hurdles that govern it (Abebe, 2023; Smallbone & Welter, 2001). Additionally, the placement of refugee entrepreneurship alongside barriers suggests this group is frequently viewed through a lens of crisis adaptation rather than as competitive business owners focused on performance (Obschonka et al., 2018). This aligns with recent observations that refugee entrepreneurial intent is often studied as a response to adverse structural constraints and the 'pains' of forced migration (Abebe, 2023).

The final cluster connects strategy with social and human capital within the context of the Covid-19 pandemic, representing the resources mobilized during crises. The proximity of the 'strategy' node to 'social capital' and 'crisis' rather than stable market variables indicates that migrant business strategy is largely reactive. In unstable environments, entrepreneurs often bypass formal institutions in favor of network theory, utilizing family and community ties to maintain continuity (Kloosterman, 2010; Abebe, 2023). Consequently, for these firms, 'strategy' is defined by the mobilization of social networks to weather regulatory storms rather than long-term growth.

3.4 Evolutionary Trends and Research Gaps

While the cluster analysis reveals the static structure of the field, the overlay and density visualizations expose the dynamic trajectory of research, highlighting a critical pivot in theoretical focus. Figure 4 serves as a "heat map" of academic attention, revealing a field that is structurally unbalanced. The map displays intense "hotspots" of bright yellow and green around "Social Capital", "Performance", and "Mixed Embeddedness", confirming that the role of social networks and embeddedness is a mature, saturated area of inquiry. In stark contrast, the concepts of "Informality", "Transition", and "Labor Market" appear in darker, low-density peripheral zones.

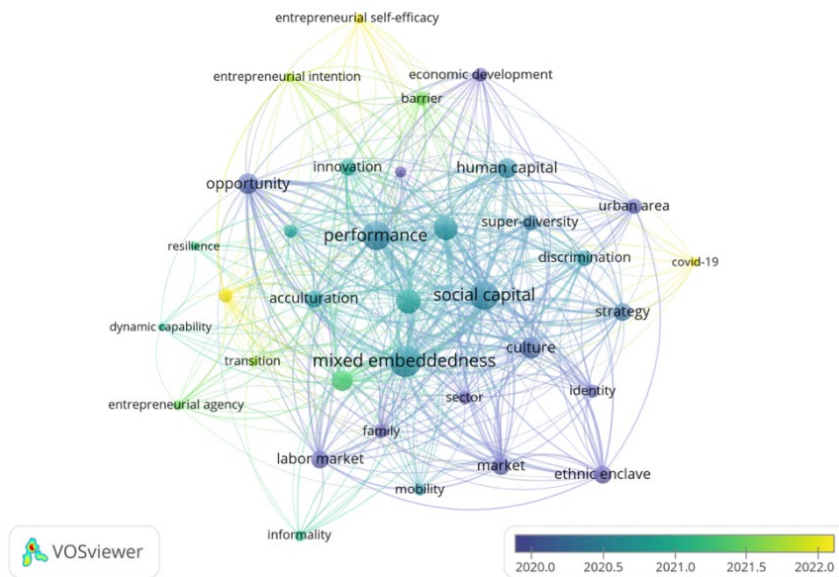


Figure 4: Overlay Visualization

Source: own.

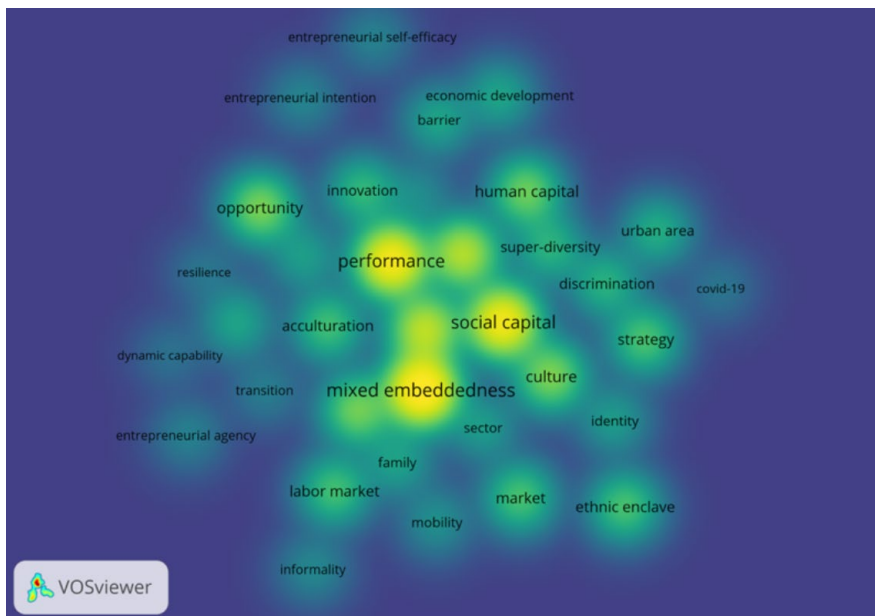


Figure 5: Density Visualization

Source: own.

This distribution reinforces the ‘standardization gap,’ indicating that the mechanisms of formalization remain underexplored—an omission that is consistent with Institutional Theory, which emphasizes the role of institutional structures in shaping market participation. Despite the importance of regulatory frameworks in transition economies, the bibliometric data suggest a limited concentration of research on how firms transition from informal to formal states. Consequently, existing scholarship remains heavily focused on social network perspectives, while the mechanics of regulatory standardization are comparatively underdeveloped.

The overlay visualization further clarifies this gap by color-coding keywords based on their average publication year, revealing a clear chronological shift in the research agenda. Traditional terms such as “Ethnic Enclave”, “Acculturation”, “Labor Market”, and “Identity” appear in dark blue, indicating that the field’s foundation was built on sociological and culturalist explanations. These studies focused on who the entrepreneurs are and where they are segregated. However, the most recent research, marked by bright yellow nodes, is defined by a distinct pivot toward internal capabilities and crisis response. Terms like “Covid-19,” “Resilience,” and “Entrepreneurial Self-Efficacy” now dominate the current discourse. The middle step is missing. This pattern reflects a ‘theoretical leapfrog,’ where sociological perspectives on ethnic enclaves and more recent psychological approaches to entrepreneurial resilience have developed more rapidly than meso-level institutional analyses. This gap suggests that the role of regulatory structures, which is central to Institutional Theory, remains under-integrated in the study of ethnic entrepreneurship. The nodes for ‘Institutional Environment’ and ‘Strategy’ remain in the middle (green), suggesting they are not the cutting-edge topics driving the current conversation. This confirms that the field is reacting to global shocks by prioritizing individual survival traits over structural reforms required for long-term growth. The research focus has effectively ‘jumped’ from sociological explanations of ‘Culture’ to psychological ‘Crisis Coping,’ bypassing the essential middle step of Standardization (see Figure 4). This theoretical ‘leapfrogging’ aligns with critiques of the ‘Resilience Paradigm,’ which often places the burden of survival on the entrepreneur while ignoring the exclusionary nature of governance frameworks (Abebe, 2023; Smallbone & Welter, 2001).

4 Discussion

Bibliometric mapping reveals a significant geographical asymmetry, with the USA and UK dominating research output. This creates a deep-seated theoretical bias, as our foundational models are calibrated to stable, liberal markets rather than the volatile reality of post-socialist transitions. Therefore, there is an urgent need for a central European school of entrepreneurship research to explicitly address the regulatory instability unique to transition economies.

Our analysis provides empirical weight for the "Standardization Gap". Findings align with the concept of 'institutional voids' (Khanna & Palepu, 2010), where the state's shift toward market regulation lacks the necessary intermediaries or support structures for small players to transition successfully (Smallbone & Welter, 2001; Mair & Marti, 2009). In this context, the 'standardization gap' reflects not merely regulatory pressure, but the absence of support mechanisms enabling compliance. Network topology confirms that current literature treats informality as a permanent trap rather than a transitional phase toward formalization. As barriers rise without corresponding aid, entrepreneurs are forced into low-return informal activities, navigating a state of "transitional informality" rather than leveraging institutions for growth.

The positioning of the "Labor Market" node alongside "Discrimination" and "Identity" provides the theoretical basis for "Regulatory Gentrification". This suggests that the mainstream labor market often functions as a site of social exclusion rather than opportunity, resonating with Vertovec's (2007) concept of "super-diversity". When regulations tighten to standardize the economy, they raise the threshold for formal participation, inadvertently pushing vulnerable entrepreneurs deeper into the enclave. This suggests that gentrification involves rising regulatory standards that systematically displace informal business formats.

This shift reflects the previously identified 'theoretical leapfrog,' where sociological and psychological perspectives have advanced more rapidly than institutional-level analyses. Consequently, the role of regulatory structures remains insufficiently integrated into the literature, limiting our understanding of how formalization processes shape entrepreneurial trajectories. A strong focus on individual 'resilience' scholarship inadvertently sanitizes structural unfairness. This "Resilience Paradigm"

places the survival burden entirely on the entrepreneur, ignoring the exclusionary nature of high-cost compliance frameworks in transition economies where formal support is scarce.

Finally, sustainable governance currently prioritizes the 'E' (Environmental) and 'G' (Governance) at the expense of the 'S' (Social). Our analysis suggests that the standardization gap effectively acts as a barrier to social sustainability by displacing ethnic micro-enterprises that provide vital community cohesion and informal safety nets. To achieve true social sustainability, governance must shift from a punitive auditor to a partner in Institutional Inclusivity. We argue that success should not be measured by compliance rates, but by the state's ability to formalize SMEs without triggering their extinction. In this light, providing administrative and financial support for micro-SME compliance becomes a key metric for socially sustainable management.

5 Conclusion

This study utilized a bibliometric analysis of 492 articles to identify the theoretical roots of the "Standardization Gap" and its role in driving "Regulatory Gentrification". The observed shift toward resilience-focused research reflects a broader tendency within Institutional Theory to underemphasize structural constraints in favor of agent-level explanations. This risks placing the burden of adaptation on entrepreneurs while overlooking the exclusionary effects of regulatory systems.

For policymakers and practitioners, these results highlight a critical paradox in sustainable governance: regulations designed for public safety inadvertently act as mechanisms of social exclusion by imposing industrial capital requirements that only those with significant private or community wealth can meet. To resolve this, this study argues that sustainable governance cannot be achieved through standardization alone; it requires the establishment of Institutional Inclusivity. In an inclusive governance framework, the state functions not merely as a punitive auditor but as a developmental partner that provides micro-SMEs with the financial and administrative support necessary to meet modern standards. By shifting the focus from individual resilience to structural institutional support, the management field can ensure that the formalization of the market does not lead to the extinction of

authentic ethnic micro-enterprises, thereby preserving the social and economic diversity of the urban landscape.

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ELECTRIC VEHICLE ADOPTION: A TPB-BASED CONCEPTUAL FRAMEWORK WITH ESG AND POLICY INSIGHTS FROM SLOVAKIA

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This paper develops a theory-driven conceptual framework based on the Theory of Planned Behaviour (TPB) to explain individual consumer adoption of electric vehicles (EVs) within the context of sustainability, ESG considerations, and public policy. Drawing on a structured review of high-quality academic literature, the study examines how attitudes, subjective norms, and perceived behavioural control influence EV adoption decisions, with particular emphasis on environmental and sustainability-related factors. The paper does not present original empirical data; instead, it proposes an extended TPB-based model tailored to EV adoption, integrating psychological, economic, infrastructural, and ESG-related dimensions. In addition, policy-relevant factors—such as financial incentives, regulatory support, and charging infrastructure—are incorporated to reflect their role in shaping consumer perceptions and behavioural control. To enhance practical applicability, the framework is operationalised through the development of measurement items for each construct, providing a foundation for future empirical research. The Slovak market is used as a contextual reference to illustrate the relevance of policy and market-specific conditions. The study contributes by linking consumer behaviour theory with ESG and policy perspectives, offering an integrated and operationalizable framework to better understand and support the transition toward sustainable mobility.

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1 Introduction

The transition toward sustainable mobility has positioned electric vehicles (EVs) as a central component of environmental, energy, and transport policies across Europe. Road transport remains a major contributor to greenhouse gas emissions within the European Union, prompting policymakers to promote EVs as a key solution for reducing emissions and achieving climate neutrality goals (European Environment Agency, 2024; International Energy Agency, 2022). Beyond their environmental benefits, EVs are increasingly embedded within Environmental, Social, and Governance (ESG) frameworks, reflecting a broader shift toward integrating sustainability into both policy and market systems.

The concept of ESG emerged from global institutional developments in the early 2000s, particularly the *Who Cares Wins* initiative led by the United Nations Global Compact, which formalized the integration of environmental, social, and governance considerations into financial decision-making (Wang & Phillips-Fein, 2023). Since then, ESG has evolved into a dominant framework guiding corporate strategies, investment practices, and public policy. In the context of EVs, ESG considerations extend beyond environmental performance to include social acceptance, institutional trust, and governance quality, all of which influence the adoption of sustainable technologies.

Despite strong policy support and technological advancements, EV adoption remains uneven across European countries. Slovakia represents a particularly illustrative case. While the country is one of Europe's leading automotive producers in terms of vehicles manufactured per capita, domestic EV adoption continues to lag behind the European Union average (ACEA, 2023). Recent evidence shows that battery electric vehicles accounted for only 2.2% of newly registered passenger cars in Slovakia in 2024, compared to 19.1% in the EU overall (Cvacho & Madleňák, 2026). This discrepancy highlights a structural gap between production capacity and consumer uptake, suggesting that supply-side developments alone are insufficient to drive the transition toward sustainable mobility.

Existing research indicates that EV adoption is a complex decision-making process influenced by economic, behavioural, social, and infrastructural factors. Financial barriers, such as high upfront costs and perceived risks, remain significant

constraints (Rezvani et al., 2015). At the same time, behavioural determinants—including attitudes, subjective norms, and perceived behavioural control—play a critical role in shaping adoption intentions, as conceptualized by the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Egbue & Long, 2012). These factors are further shaped by contextual conditions such as charging infrastructure, government incentives, and institutional trust (Fang et al., 2020). More recently, ESG-related perceptions—such as environmental concern, social responsibility, and trust in governance—have emerged as additional influences on consumer behaviour.

While TPB provides a robust framework for explaining individual decision-making, it does not explicitly incorporate broader ESG dimensions. At the same time, existing ESG research has primarily focused on firm-level performance and sustainable business development, with limited attention to its role in shaping individual consumer behaviour (Hsu, 2024). This creates a gap in the literature, particularly in the context of EV adoption, where behavioural and sustainability perspectives remain insufficiently integrated.

Against this background, the present study develops a conceptual framework of EV adoption based on the Theory of Planned Behaviour, extended with ESG and contextual factors. Focusing on Slovakia, the study adopts a literature-based approach to integrate behavioural, economic, infrastructural, and sustainability-related determinants into a unified model. In addition, it proposes measurement items to operationalize the constructs, providing a foundation for future empirical research. By bridging TPB with ESG considerations, the study aims to contribute to a more comprehensive understanding of EV adoption and to offer insights for policymakers and practitioners seeking to accelerate sustainable mobility transitions.

2 Theoretical Background

Building on the Theory of Planned Behaviour (TPB) and prior research on sustainable consumption and electric vehicle (EV) adoption, this study proposes a conceptual model integrating behavioural, contextual, and sustainability-related determinants. According to the European Alternative Fuels Observatory, Slovakia's 2025 incentive framework offers no direct BEV purchase subsidies but provides tax-based benefits (reduced registration tax, full annual road tax exemption), company-related tax reductions (0.5% benefit-in-kind rate), and municipal perks like

preferential parking. This evolving policy landscape offers a relevant empirical context for examining how TPB constructs interact with real-world incentives to shape EV adoption intentions.

Consumer behaviour research provides a strong theoretical foundation for explaining EV adoption decisions. Among the most influential frameworks is the TPB (Ajzen, 1991), which posits that behavioural intention is determined by three core components: attitudes toward the behaviour, subjective norms, and perceived behavioural control (PBC). PBC in TPB parallels perceived ease of use in the Technology Acceptance Model (TAM), though TPB is a general framework applicable to sustainable consumption choices such as EV adoption (Ajzen, 2020). A substantial body of literature confirms TPB's explanatory power in the EV context. Positive attitudes toward EVs—driven by environmental awareness, cost savings, and technological novelty—significantly enhance purchase intention (Rezvani et al., 2015). These sustainability-oriented motivations can also be contextualized within the Environmental, Social, and Governance (ESG) framework, which emphasizes the interconnection of environmental stewardship, social responsibility, and governance practices (Meiden & Silaban, 2023; Estevez-Mendoza & Infante, 2025).

PBC plays a decisive role in EV adoption. Factors such as charging availability, driving range, and perceived ease of use strongly influence consumers' sense of control (Egbue & Long, 2012; Skippon & Garwood, 2011). ESG-aligned governance measures—such as incentives and infrastructure investment—can enhance PBC by reducing practical barriers (Meiden & Silaban, 2023). Subjective norms, referring to perceived social pressure from family and peers, also shape adoption intentions, particularly in early diffusion stages where consumers rely on social validation (Rogers, 2003; Jansson et al., 2017). Beyond TPB, perceived risk theory explains consumer resistance toward EVs. Financial risk, battery lifespan concerns, and resale value anxiety are major adoption barriers (Lin & Wu, 2018). Innovation resistance theory highlights how habitual reliance on internal combustion engine vehicles delays acceptance (Ram & Sheth, 1989). ESG-oriented policies can mitigate such barriers through regulatory guidance and green innovation incentives.

PBC is heavily influenced by access to charging infrastructure. Dedicated infrastructure, such as Level 2 and DC fast chargers, enhances consumer confidence and perceived control over vehicle usage (Hardman et al., 2021). Value-based perspectives, including Value–Belief–Norm theory, suggest that individuals with strong ecological values exhibit higher willingness to adopt EVs (Nordlund & Garvill, 2003; Rezvani et al., 2018). Recent research adopts integrated models combining TPB with perceived risk, moral norms, and contextual variables to improve explanatory power (Hardman et al., 2021). These hybrid approaches demonstrate that EV adoption is shaped by the interplay of psychological, economic, infrastructural, and sustainability-oriented factors, with ESG considerations serving as a critical contextual layer.

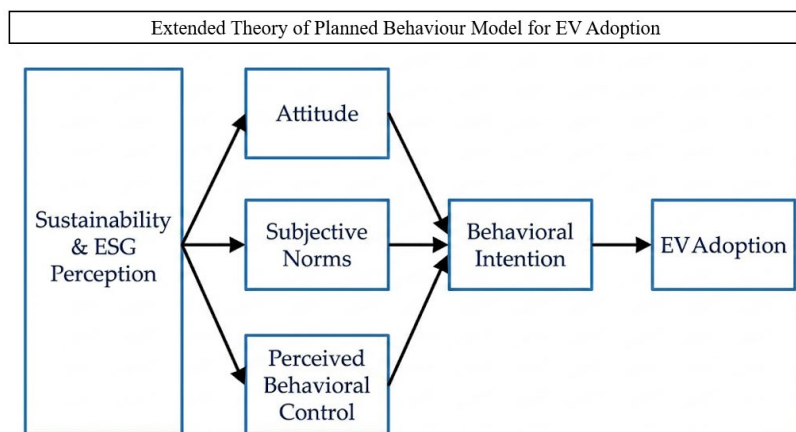


Figure 1: Extended Theory of Planned Behaviour model for electric vehicle adoption.

Source: Adapted from Ajzen (1991, 2020) and enriched with sustainability (ESG)-related determinants based on prior literature.

In the Slovak context, infrastructure availability and financial incentives have been identified as key barriers to BEV adoption, directly influencing consumers' PBC and purchase intentions (Cvacho & Madleňák, 2026). According to SEVA (2025), as of March 31, 2025, there were 17,430 BEVs registered on Slovak roads, with BEVs accounting for 4.7% of new registrations versus the EU average of 15.3%. Annual registration data reveal fluctuating trends: 2,505 in 2022, 3,470 in 2023 (a 38.5% increase), followed by a decline to 3,073 in 2024 (an 11.4% decrease) (Ministerstvo vnútra SR, 2025). These variations suggest that EV adoption in Slovakia remains

sensitive to changing incentives, economic conditions, and consumer perceptions, indicating evolving but still cautious acceptance among Slovak consumers. Overall, the literature confirms that while TPB remains a robust framework, its explanatory strength is enhanced when complemented by risk-related, normative, and ESG-aligned perspectives. As shown in Figure 1, the model is grounded in TPB (Ajzen, 1991, 2020) while incorporating additional determinants such as environmental concern, infrastructure, and policy-related factors.

3 Methodology

This study employs a qualitative, literature-based research design to develop a Theory of Planned Behaviour (TPB)-based conceptual framework for electric vehicle (EV) adoption, enriched with ESG and policy perspectives, with a particular focus on Slovakia. The approach is suitable for emerging research domains where theoretical integration is required prior to large-scale empirical validation.

A structured narrative literature review was conducted to synthesise existing academic knowledge on EV adoption from a consumer behaviour perspective. The review included peer-reviewed journal articles, academic books, and selected policy and industry reports. The methodological approach follows established guidelines for qualitative evidence synthesis and conceptual research development (Tranfield et al., 2003; Snyder, 2019). This enables systematic integration of fragmented findings across disciplines such as marketing, environmental psychology, and sustainable transport studies.

Literature was identified through Scopus, Web of Science, and Google Scholar using targeted keywords, including “electric vehicle adoption”, “consumer behaviour”, “Theory of Planned Behaviour”, “charging infrastructure”, and “sustainability”. The selection process prioritised high-impact, peer-reviewed studies with clear theoretical grounding and empirical rigor. Special emphasis was placed on European contexts, particularly where evidence relevant to Slovakia or comparable Central and Eastern European markets was available. Policy documents and institutional reports were included selectively to contextualise regulatory and infrastructural developments.

Data analysis was conducted using thematic synthesis, enabling the systematic coding and aggregation of findings across heterogeneous sources (Braun & Clarke, 2006; Thomas & Harden, 2008). Extracted determinants were organised into four analytical dimensions aligned with the conceptual framework: (1) psychological factors (attitudes, subjective norms, perceived behavioural control), (2) financial factors (purchase cost, incentives, perceived economic risk), (3) infrastructural factors (charging availability, accessibility, and reliability), and (4) sustainability- and ESG-related factors (environmental concern and ethical considerations).

This structured synthesis supports the development of an integrated TPB-based framework that extends traditional behavioural models by incorporating contextual and sustainability-related determinants relevant to EV adoption. While the study does not involve primary data collection, the systematic and theory-driven approach ensures conceptual rigor and provides a strong foundation for future empirical testing, particularly in the Slovak market context.

4 Results

This study synthesizes findings from a structured review of academic literature on electric vehicle (EV) adoption, with particular focus on consumer behaviour through the Theory of Planned Behaviour (TPB), as well as ESG-related considerations and policy developments in Slovakia and comparable European contexts. The results are organized around the core TPB constructs—attitude, subjective norms, and perceived behavioural control—followed by additional themes related to infrastructure, cost perception, environmental awareness, and policy influence.

4.1 TPB Constructs and EV Adoption Behaviour

Across the reviewed literature, attitude toward EVs emerges as the most consistent and influential determinant of adoption intention. Consumers generally associate EVs with environmental benefits, lower operating costs, and technological progress. However, these positive perceptions are often weakened by concerns regarding high purchase prices and charging convenience.

Subjective norms also contribute to adoption intention, particularly in socially interconnected European contexts. Individuals are more likely to consider EV adoption when peers, family members, or social groups view EVs positively. This effect is stronger in early adoption phases, where visibility of EV ownership remains limited but socially influential.

Perceived behavioural control (PBC) is identified as a key limiting factor. Consumers' perceived ability to adopt EVs is strongly shaped by external conditions such as charging infrastructure availability, driving range limitations, and access to home charging. PBC often restricts adoption even when attitudes are favourable.

4.2 ESG-Related Motivations

Environmental and sustainability concerns reinforce EV adoption intentions. EVs are increasingly associated with reduced emissions and alignment with ESG values. However, the strength of this effect varies, with younger and environmentally conscious consumers showing higher responsiveness. Corporate sustainability strategies and ESG reporting also indirectly influence perceptions by shaping legitimacy and trust in EV technology.

4.3 Policy and Economic Context

Policy frameworks play a decisive role in shaping EV adoption. In many European countries, subsidies, tax exemptions, and infrastructure investments significantly support uptake. In Slovakia, however, support is more limited, with emphasis on tax-based incentives and gradual infrastructure development. As a result, adoption is more dependent on consumer financial capacity and private sector readiness.

4.4 Emerging Barriers

Key barriers include high upfront costs, insufficient charging infrastructure, range anxiety, and a limited second-hand EV market, all of which reduce affordability and usability.

4.5 Summary of Key Patterns

Overall, EV adoption is a multidimensional process driven by both psychological and structural factors. While TPB provides a strong explanatory foundation, ESG and policy conditions act as important moderators. In Slovakia, structural constraints remain the dominant limiting factor for widespread adoption.

5 Discussion and Recommendations

The findings confirm that electric vehicle (EV) adoption is shaped by a combination of psychological, social, and structural factors consistent with the Theory of Planned Behaviour (TPB). However, TPB alone is insufficient to fully explain adoption, as external constraints such as infrastructure, cost, and policy support play a decisive role in translating intention into actual behaviour.

Among TPB constructs, attitude toward EVs is the strongest positive driver. Consumers generally associate EVs with environmental benefits, lower operating costs, and technological progress. Despite this, a clear gap remains between positive attitudes and actual purchase behaviour, indicating that favourable perception does not automatically lead to adoption.

Subjective norms have a weaker and context-dependent influence. In Slovakia, limited EV penetration reduces visibility and social pressure, which restricts the impact of social influence. This suggests that normative effects are still developing and may strengthen as EV adoption becomes more widespread.

Perceived behavioural control (PBC) is the most significant barrier. High upfront costs, insufficient charging infrastructure, and range anxiety reduce consumers' perceived ability to adopt EVs. Even with positive attitudes, low PBC limits adoption, highlighting the dominance of structural constraints in the Slovak context. Beyond TPB, ESG-related motivations reinforce positive attitudes, particularly among environmentally conscious consumers, but are not strong enough to overcome financial and infrastructural limitations. ESG factors mainly support long-term behavioural change rather than immediate adoption.

The policy environment in Slovakia further shapes these dynamics, as limited direct subsidies and gradual infrastructure development reduce adoption momentum compared to more advanced EU markets.

To accelerate EV adoption, policy efforts should focus on expanding charging infrastructure and improving accessibility to strengthen perceived behavioural control. Financial incentives such as purchase subsidies or tax reductions are also necessary to address cost barriers. In addition, awareness campaigns highlighting both environmental and practical benefits can strengthen consumer attitudes. Finally, integrating ESG principles into public and corporate strategies can support long-term market development.

6 Conclusions

This study examined electric vehicle (EV) adoption through a TPB-based conceptual framework, extended with ESG considerations and policy insights focused on Slovakia. The findings show that EV adoption is shaped by a combination of psychological intentions and external structural conditions.

Within the Theory of Planned Behaviour, attitude toward EVs is generally positive, driven by environmental benefits, cost efficiency, and technological appeal. However, this positive attitude does not consistently lead to actual purchase decisions, indicating a clear intention–behaviour gap. Subjective norms have a limited influence in the Slovak context due to relatively low EV visibility and early-stage market development. Perceived behavioural control is identified as the strongest determinant, with infrastructure limitations, high upfront costs, and range concerns significantly constraining adoption.

ESG-related factors strengthen positive attitudes, particularly among environmentally conscious consumers, but mainly act as supporting rather than primary drivers. Their influence is long-term and dependent on broader market maturity. The Slovak policy environment, characterized by limited direct purchase incentives and gradual infrastructure development, further slows adoption dynamics compared to more advanced European markets.

Overall, EV adoption in Slovakia is primarily constrained by structural and economic barriers rather than consumer resistance. While intention exists, enabling conditions remain insufficient for widespread adoption.

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AI-ENABLED ESG INTEGRATION IN BANKING DECISION-MAKING: GOVERNANCE IMPLICATIONS IN EUROPEAN AND EMERGING FINANCIAL SYSTEMS

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This study analyses how artificial intelligence (AI) enables the integration of environmental, social, and governance (ESG) factors into banking decision-making and examines its implications for sustainable governance in developed and developing financial systems. The study adopts a qualitative, multi-case comparative design based on the documentary analysis of ESG reports, annual reports, risk management reports, and governance documents from selected banks. The sample includes European banks with advanced AI–ESG integration, namely ING Group, BNP Paribas, Nordea Bank, and NLB Group Slovenia, alongside Raiffeisen Bank Kosovo as a case from a developing financial system. Methodologically, the study employs qualitative documentary analysis through deductive–inductive content analysis, supported by cross-case comparison and selective process tracing, to examine the links among ESG data, AI-based analytics, and financial decision-making. The findings indicate that European banks have more deeply embedded AI and ESG into risk management, lending, and portfolio allocation, supported by stronger governance and control mechanisms. In contrast, banks in emerging financial systems show partial integration, mainly focused on reporting and regulatory compliance. The study highlights the need to strengthen AI governance, transparency, and model risk management to support sustainable banking decision-making.

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1 Introduction

In recent years, integrating environmental, social, and governance (ESG) factors has become a strategic priority for banks, driven by regulatory pressures, investor expectations, and stakeholder demands for a more sustainable financial system. EU frameworks such as the Green Deal, Taxonomy, and Corporate Sustainability Reporting Directive (CSRD) have raised transparency requirements, strengthened sustainability risk management, and embedded ESG into financial decisions. Meanwhile, Artificial Intelligence (AI) and advanced data analytics are transforming how banks analyze risk, assess clients, and allocate capital. Combining AI with ESG data enables more accurate assessment of climate, social, and governance risk, supporting financial institutions' long-term sustainability. However, differences in technological and institutional development between developed and developing financial systems pose distinct challenges for effective AI–ESG integration.

The literature has discussed ESG's role in financial performance and risk management, as well as AI's impact on banking's digital transformation. However, few studies examine how banks integrate AI and ESG in decision-making. Most research examines these areas separately and does not address how advanced analytics embed sustainability in lending, portfolio management, or risk assessment. Additionally, most evidence comes from developed economies; there is a need for comparative studies on emerging financial systems, where data infrastructure, tech capacity, and governance may hinder AI–ESG integration.

In this context, the aim of this study is to analyse how Artificial Intelligence enables the integration of ESG factors into banking decision-making. The study also assesses the implications of this process for sustainable governance in developed and emerging financial systems. Specifically, it aims to identify the main practices for using AI to process and integrate ESG data into decision-making. It further analyzes the role of governance and control mechanisms in managing risks associated with models and analytics. The study also compares the level and depth of AI–ESG integration between European Union banks and a bank in an emerging financial system. The main research question is: How and to what extent does AI contribute to the effective integration of ESG factors into banking decision-making? What are the implications for sustainable governance in different institutional contexts?

This paper provides an integrated view of how digital transformation and sustainable finance interact, linking AI use to governance and risk management in banking. A comparative analysis of mature and emerging financial systems highlights the structural and institutional differences shaping AI–ESG integration. For bank executives and policymakers, the results underscore the need to strengthen AI governance, boost algorithmic transparency, and develop institutional capacity for effective model risk management and sustainable financial decision-making.

This study contributes to the existing literature in three main directions. First, unlike most previous studies that treat artificial intelligence, ESG integration, or sustainable finance separately, this paper analyzes these dimensions in an integrated manner within banking decision-making processes. Second, the study expands the comparative framework to include both European banks with more advanced AI–ESG integration and a case from an emerging financial system, thereby enabling the identification of institutional, technological, and regulatory differences. Third, the paper's original contribution lies in the analytical link between ESG data, advanced analytics/AI, governance mechanisms, and financial decision-making, offering theoretical implications for the literature on sustainable governance and practical implications for bank managers, regulators, and policymakers.

2 Literature Review

The integration of environmental, social, and governance (ESG) factors in the financial sector has intensified significantly in recent years, driven by regulatory pressures, investor demands, and increasing risks related to climate change and sustainability. At the same time, developments in artificial intelligence (AI) and advanced data analytics have transformed the way financial institutions analyze information, assess risk, and support decision-making. Against this backdrop, recent literature has expanded significantly in two main directions: the use of AI to process and assess ESG data, and the impact of these factors on financial performance and stability. Nevertheless, the evidence remains fragmented and often treats AI and ESG as separate fields. To address this gap, this review uses a synthesizing and comparative approach to organize the literature into four main areas: (1) technological approaches to AI in ESG, (2) impact on financial decision-making, (3) governance and regulatory challenges, and (4) existing practices and factors of success or failure.

From a foundational perspective, ESG integration is closely linked to stakeholder theory and the broader evolution of corporate sustainability. Stakeholder theory argues that firms should not be governed solely in shareholders' interests, but should also consider the expectations and interests of wider stakeholder groups, including customers, employees, regulators, communities, and the environment. In the banking sector, this perspective is particularly relevant because financial institutions influence capital allocation, risk distribution, and long-term economic resilience. Therefore, ESG integration can be understood not only as a reporting practice, but also as a governance mechanism through which banks internalize environmental, social, and governance-related risks into strategic and financial decision-making (Freeman, 1984; Eccles et al., 2014).

2.1 Artificial Intelligence - Driven Data Analytics and Technological Approaches for ESG Integration

The literature indicates that one of the main contributions of artificial intelligence to ESG integration is the improvement in the processing, assessment, and interpretation of sustainability-related data. Machine learning models can support ESG rating prediction by combining financial and non-financial indicators, while explainable AI techniques, such as SHAP and ensemble learning, enhance transparency into the factors influencing ESG performance. In addition, the digitalization of sustainability indicators and their integration into big data systems enable more systematic monitoring of environmental, social, and governance risks. These developments suggest that AI can enhance ESG analysis not only by increasing processing speed, but also by improving the consistency, scalability, and interpretability of sustainability assessments (Cini & Ferrari, 2025; Lee et al., 2025; Telukdarie et al., 2024; Zhang & Zhao, 2026; Zhao & Jin, 2025).

At the same time, ESG data remain affected by measurement uncertainty and rating divergence. A key challenge identified in the literature is the inconsistency of ESG ratings across providers, which can weaken the reliability of ESG-based financial analysis and decision-making. This problem is linked to broader debates on ESG measurement, where indicators are shaped by rating methodologies, disclosure quality, sectoral differences, and normative assumptions about sustainability performance. In banking, this creates an important methodological challenge: AI-enabled ESG analysis is only as reliable as the quality, comparability, and governance

of the underlying data. Therefore, despite rapid technological progress, there is still limited evidence on how AI-based ESG analytics are translated into concrete banking decisions, particularly in lending, risk management, and portfolio allocation (Berg et al., 2022; Davidescu et al., 2025; Dinaj & Morina, 2025; Morina & Dinaj, 2025).

2.2 The Role of AI - ESG Integration in Financial Decision-Making and Risk Management

The discussion on ESG integration in banking decision-making should be situated within the broader framework of sustainable finance. Sustainable finance emphasizes that financial decisions should incorporate long-term environmental and social externalities, rather than relying exclusively on short-term financial indicators. In this perspective, ESG factors become relevant inputs for credit assessment, investment allocation, risk pricing, and portfolio strategy. For banks, this implies a shift from traditional risk-return analysis toward a broader governance framework that integrates climate risk, social responsibility, and institutional accountability into financial decision-making (Schoenmaker & Schramade, 2018).

Recent studies show that ESG factors are increasingly associated with financial stability, reduced systemic risk, and sustainability-oriented portfolio allocation. In parallel, AI models are being used to improve credit scoring, financial stress analysis, early-warning systems, and explainable decision-making in banking. These developments indicate that AI and ESG can jointly support more informed risk assessment and capital allocation when they are embedded in structured governance and data systems. However, much of the existing literature still examines ESG and AI separately, while fewer studies analyze how AI-enabled ESG analytics are incorporated into banks' strategic and operational decision-making processes (Bouattour et al., 2024; de Lange et al., 2022; Del Fava et al., 2024; Hamdouni, 2025; Hu et al., 2025; Lin & Jin, 2023; Morina & Dinaj, 2024; Morina, 2024; Morina, 2025).

2.3 Governance, Regulatory Frameworks, and Model Risk in AI-Enabled Sustainable Finance

AI governance should be understood through foundational principles of trustworthy and responsible artificial intelligence. These principles emphasize transparency, accountability, robustness, fairness, human oversight, and risk management throughout the AI life cycle. In financial institutions, such principles are particularly important because AI-supported decisions may affect credit access, customer risk assessment, compliance monitoring, and portfolio allocation. Therefore, AI governance is not limited to technological control, but also includes institutional accountability, model validation, explainability, auditability, and alignment with regulatory and ethical standards (OECD, 2019; European Commission & High-Level Expert Group on Artificial Intelligence, 2019).

The growing use of AI in finance has introduced new governance challenges, including model explainability, data protection, algorithmic bias, operational risk, institutional accountability, and regulatory harmonization. These challenges are especially relevant in banking, where AI-based systems can influence lending, risk monitoring, and customer evaluation. Recent literature emphasizes the need for robust control mechanisms, audit processes, responsible AI frameworks, and international regulatory coordination to ensure that AI adoption supports innovation without increasing ethical, regulatory, or reputational risks. However, AI governance and ESG governance are still often discussed separately, leaving a gap in understanding how model risk, ESG reporting, and sustainability-oriented decision-making interact within banking institutions (Ali et al., 2025; Bahoo et al., 2024; Batool et al., 2025; Černevičienė & Kabašinskas, 2024; Emery-Xu et al., 2025; Fundira & Mbohwa, 2025; Pisoni & Moloney, 2024; Ridzuan et al., 2024).

Recent studies further underscore the need for a broader, more integrated understanding of ESG, sustainability indicators, and AI governance in financial decision-making. Circular economy principles can enrich ESG assessment by introducing new sustainability metrics, while quantitative sustainability frameworks help connect environmental, institutional, and social development indicators. In banking, AI is increasingly used to optimize financial operations and support data-driven decision-making, but algorithmic credit decisions also raise concerns about transparency, accountability, and the right to explanation. These studies reinforce

the argument that AI–ESG integration in banking should be examined not only as a technological process, but also as a governance, measurement, and accountability challenge (Macher & Szigeti, 2025; Nagy-Rádli et al., 2025; Singh et al., 2025; Lui et al., 2025).

2.4 Implementation Practices, Success Factors, and Structural Barriers in AI–ESG Adoption

Empirical studies on banking-sector practices show uneven levels of ESG and AI–ESG integration across institutions and regions. Banks in more developed financial systems have increasingly incorporated ESG factors into stress testing, risk management, lending policies, and capital strategies. In contrast, in many emerging or less institutionally developed contexts, ESG implementation remains more closely linked to compliance, reporting, and reputational risk management. The literature identifies several critical success factors for deeper integration, including ESG data quality, analytical capabilities, senior management support, governance maturity, and regulatory pressure (Acharya et al., 2023; Garefalakis et al., 2025; Gonzalez-Ruiz et al., 2024; Rania, 2026; Zairis et al., 2024).

From a broader sustainability perspective, green economy indicators and sustainability-oriented financial strategies provide additional tools for assessing long-term performance and institutional resilience. However, comparative studies that examine how AI and ESG are jointly integrated into banking decision-making across developed and developing financial systems remain limited. This gap is particularly relevant because emerging financial systems often face constraints related to data availability, digital infrastructure, regulatory capacity, and external assurance mechanisms. As a result, the depth of AI–ESG integration depends not only on technological adoption, but also on the institutional conditions that allow ESG data and AI-based analytics to influence financial decisions (Elezaj et al., 2025; Morina et al., 2025; Morina & Elezaj, 2025).

2.5 Research Gaps and Positioning of the Study

The literature review reveals three main gaps. First, most studies examine AI, ESG integration, and sustainable finance as separate research domains, while paying limited attention to their combined role in banking decision-making. Second, the

governance literature often addresses AI regulation, model risk, or ESG reporting independently, without sufficiently explaining how these dimensions interact in financial institutions. Third, empirical evidence remains concentrated in developed economies, while comparative research that includes emerging financial systems is still limited. This study addresses these gaps by analyzing how AI-enabled analytics support the use of ESG data in banking decision-making and how governance mechanisms shape this process. By comparing selected European banks with a bank operating in an emerging financial system, the study contributes to the literature on digital transformation, sustainable finance, and banking governance by identifying differences in institutional maturity, data infrastructure, and AI–ESG integration.

3 Scientific Research Methodology

This study is built on the epistemological paradigm of interpretivism, which is based on the premise that institutional and organizational reality is not an independent objective entity, but a social construct formed through practices, actors' interpretations, and regulatory context. The integration of artificial intelligence and ESG factors in the banking sector is not merely a technical transformation but a complex institutional process encompassing governance mechanisms, organizational culture, decision-making structures, and regulatory dynamics. In this sense, the interpretivist approach is appropriate for analyzing how banks conceptualize, operationalize, and institutionalize AI–ESG integration across their strategic and operational processes. The study does not aim to test hypotheses in the positivist sense, but to explore the mechanisms and meanings that construct this integration in different financial contexts.

In line with this paradigm, an exploratory multiple-case research design was adopted. The exploratory approach is justified by the fact that joint AI–ESG integration in banking decision-making is a relatively new phenomenon and still understudied in the literature, especially in comparative analyses between developed and developing financial systems. The multiple-case design allows for in-depth analysis within each case and systematic comparison across cases, providing a more complete understanding of institutional, technological, and regulatory variations. Through this approach, the study aims to identify common patterns of integration and structural differences across financial systems at different levels of development. The study is guided by several interrelated research questions. First, it analyzes how artificial

intelligence technologies are integrated into the processing and use of ESG data in selected banks. Second, it examines the impact of this integration on financial decision-making and risk management processes. Third, it assesses the governance mechanisms and control structures that support the implementation of AI–ESG. Finally, institutional differences between banks in developed and developing financial systems are identified in relation to this transformation process.

The selection of cases was carried out through a purposive approach, based on criteria related to the level of ESG integration, adoption of digital technologies, and documentary transparency. The cases included from the European Union include ING Group (Netherlands), BNP Paribas (France), Nordea Bank (Finland), and NLB Group (Slovenia), which are known for their advanced engagement in ESG reporting and digital transformation. Raiffeisen Bank Kosovo is included as a case from a developing financial system, which provides a relevant perspective for comparative analysis in a less consolidated institutional and regulatory context. This selection allows exploration of structural differences and technological capacities across contexts.

The study relies mainly on secondary documentary data, which include annual financial reports, ESG and sustainability reports, risk management documents, corporate governance policies, digital strategies, and public regulatory documents. The use of official documentation provides a solid basis for analysis and allows tracking the evolution of AI–ESG integration practices over time. The data were systematically analyzed to identify congruences between strategic discourse and implementation practices.

In the analytical aspect, qualitative documentary analysis was initially applied to identify how banks articulate the integration of AI and ESG in their strategic and operational documentation. Next, a deductive–inductive content analysis was used. In the deductive phase, initial coding was based on theoretical categories derived from the literature, including AI integration, ESG metrics, risk management, and governance mechanisms. In the inductive phase, new themes emerge from the empirical analysis of the documents, expanding the conceptual framework beyond the initial theoretical predictions. This hybrid approach enables a balance between theoretical structuring and openness to empirical evidence.

The coding process was conducted in several sequential stages to ensure transparency and analytical consistency. An initial set of about 12 deductive codes was created, drawn from the literature and the study's research objectives, including AI integration, ESG indicators, risk management, credit decision-making, AI governance, model control, and regulatory transparency. During the systematic reading of bank reports and governance documents, these codes were revised and expanded inductively, identifying new sub-themes such as ESG data quality, the use of proxy indicators, preventing greenwashing, the role of oversight committees, and institutional constraints in emerging financial systems. To increase the reliability of the analysis, coding was carried out iteratively, continuously comparing theoretical categories with documentary evidence and rechecking key-coded fragments to ensure consistency among data, themes, and analytical interpretations. This approach enabled the analysis to move beyond solely descriptive analysis and to identify connections between ESG data, the use of AI/advanced analytics, governance mechanisms, and financial decision-making.

Table 1 presents the methodological clarification of the process of case selection, coding development, analytical validation, and selective use of process tracing to strengthen the transparency and reliability of the qualitative analysis.

Table 1: Clarification of Case Selection, Coding Process and Process Tracing Logic

Methodological component	Clarification added to strengthen methodological precision
Case selection logic	Cases were selected purposively based on three main criteria: ESG maturity, level of AI/digital adoption, and availability of transparent documentary evidence. ING Group, BNP Paribas, Nordea Bank, and NLB Group were selected because they represent European banking systems with more developed ESG governance, digital transformation, and public reporting. Raiffeisen Bank Kosovo was selected to provide a comparative case from a developing financial system with different institutional, regulatory, and technological conditions.
Initial deductive coding	The initial coding framework included approximately 12 deductive codes derived from the literature and research objectives, such as AI integration, ESG metrics, credit decision-making, portfolio allocation, risk management, AI governance, model risk, transparency, regulatory compliance, and institutional constraints.
Inductive refinement	During document analysis, additional inductive sub-themes emerged, including ESG data quality, proxy indicators, greenwashing prevention, committee-level oversight, external assurance limitations and the maturity gap between developed and emerging financial systems.

Methodological component	Clarification added to strengthen methodological precision
Coding validation	Coding was conducted iteratively by comparing coded evidence across reports, revisiting key fragments and checking the consistency between documentary evidence, thematic categories and analytical interpretations. This strengthened reliability and reduced the risk of subjective interpretation.
Selective use of process tracing	Process tracing was used selectively because the study relies on public documentary evidence rather than internal bank data. It was applied only where documents allowed a reasonable reconstruction of the link between ESG data, AI/analytics, risk assessment, financial decision-making and governance oversight.
Evidence for causal links	Causal links were inferred from documentary evidence such as ESG questionnaires, climate risk assessment tools, AI governance committees, model risk controls, data-quality methodologies, sustainability reporting controls and credit decision procedures.

Source: Author's own elaboration based on the methodological design of the study.

After analyzing each case, we conducted a cross-case comparative analysis and identified common patterns and systematic differences. This phase compared levels of AI–ESG integration, the use of analytics in decision-making, and governance mechanisms. To clarify causal links, we applied the process-tracing method selectively to reconstruct how ESG data processing, through AI analytics, informs financial decision-making and governance oversight. This approach highlighted institutional mediations and key control points at each process stage.

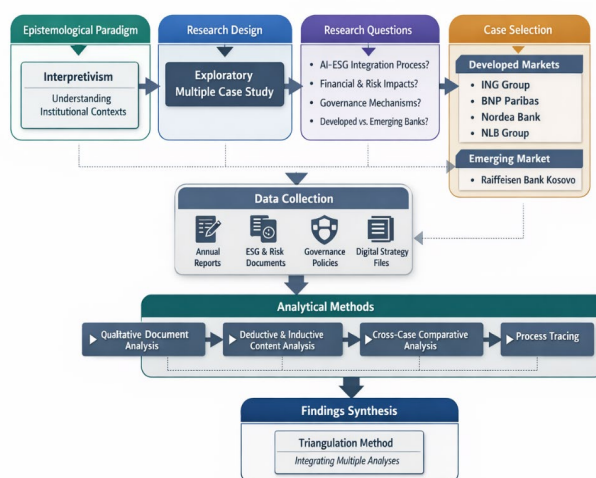


Figure 1: Conceptual and Methodological Framework of the Study

Source: Author's elaboration based on the research design (2026)

Figure 1 shows the methodological framework of the study. It illustrates the logical flow from the epistemological paradigm and exploratory design, through case selection and data collection, to the analytical methods and the triangulation of findings.

To increase the validity and reliability of the findings, methodological triangulation was used, combining documentary analysis, content analysis, cross-case comparisons, and process tracing. Triangulation enabled verification of the consistency of evidence from different sources and reduced the risk of biased interpretation. Through this integrated methodological approach, the study provides an in-depth and systematic analysis of AI–ESG integration in the banking sector, contributing to the understanding of the institutional and structural mechanisms that shape sustainable digital and financial transformation.

4 Results and Findings

4.1 ING Group (Netherlands) – Institutional integration of AI–ESG

ING's annual reporting presents digital transformation, analytics, and AI as organizational capabilities that support value creation, risk management, and operational efficiency. The bank reports using AI and GenAI across several domains, including compliance/KYC, customer service, lending support, and software engineering. It also describes the development of a unified data analytics and AI environment to improve consistency across analytical initiatives, simplify risk assessment, and strengthen data governance (ING Bank N.V., 2025).

From an AI-ESG governance perspective, the most relevant evidence is ING's treatment of AI as both an operational tool and a source of model and regulatory risk. The report links AI use to risks related to data, algorithms, incorrect outputs, bias, privacy, and accountability, and refers to dedicated oversight structures, such as the Central AI Risk Committee, as well as AI-related control mechanisms. Institutionally, ING's reporting indicates a relatively advanced level of AI integration in decision-making processes, while also suggesting that the reliability of AI-supported ESG and risk analytics depends on data governance, model control, and regulatory compliance. Since this interpretation is based on public documentary

evidence, it should be understood as an analytically inferred pattern rather than direct verification of internal operational implementation.

4.2 BNP Paribas (France) – Institutional integration of AI–ESG

BNP Paribas presents AI as part of its broader innovation and digital transformation strategy, emphasizing its role in processing large volumes of data, improving efficiency, and strengthening risk management. The group's reporting refers to the industrialization of AI use cases and highlights a cautious approach to GenAI, shaped by regulatory requirements, data security, and responsible AI principles. The existence of a responsible AI charter and strengthened governance infrastructure indicates that AI is treated not only as a tool for operational optimization but also as an area requiring institutional control and regulatory legitimacy (BNP Paribas, 2023).

Additional evidence from BNP Paribas Bank Polska S.A. indicates how this digital transformation is operationalized within the broader group ecosystem through data platforms, GenAI-based tools, chatbots, and software development support systems. These initiatives suggest that AI-enabled analytics are increasingly used to strengthen data-driven processes and organizational efficiency, while also requiring appropriate governance and control mechanisms (BNP Paribas Bank Polska S.A., 2024).

For the purposes of this study, BNP Paribas provides evidence of how AI and advanced analytics can support ESG-related risk assessment and decision-making. The bank's documentation suggests that ESG data may inform client assessment, climate risk analysis, allocation models, and monitoring processes, although the public reports do not fully disentangle all causal pathways between AI use and specific financial decisions. Therefore, BNP Paribas is interpreted as a case where AI-enabled analytics and ESG governance are increasingly connected, but where the depth of operational implementation remains partly inferred from documentary evidence.

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4.3 Nordea Bank (Finland) – Institutional integration of AI-ESG

In the 2025 annual report, Nordea places sustainability reporting within an internal control and risk management framework, where the Group Risk function defines the taxonomy of ESG risk factors and guides the integration of ESG impacts/risks/opportunities into strategy and risk management; the reporting process is monitored by various committees and reported to board committees (e.g., Operations and Sustainability; Audit) (Nordea, 2025). For the AI/analytics component, Nordea's official web resources make the spectrum of operational uses of AI clearer: Nordea describes uses that include “knowledge assistants”, “deep analytics” tools, personalization of customer communication, and uses in financial crime prevention (Nordea, 2025). Nordea also presents AI as an enabler for “conversational banking”, automation of internal tasks, faster delivery of insights and fraud detection, linking it to the customer experience and increased digital interactions (Nordea, 2025).

Nordea presents an architecture in which ESG is integrated through a “risk taxonomy” and reporting controls, while AI is positioned as a technology layer that improves efficiency, personalization, and protection against financial/operational risks (e.g., financial crime).

4.4 NLB Group (Slovenia) – Institutional integration of AI-ESG

The 2024 Annual Report provides a strong basis for institutional analysis because it clearly documents the sustainability governance architecture and its connection to decision-making structures. NLB describes the existence of board committees (e.g., Audit, Risk, Nomination, Remuneration, Operations, and IT) that participate in sustainability issues, as well as committees dedicated exclusively to sustainability (e.g., Sustainability Committee, Climate Change Committee). The Sustainability Committee is described as a central advisory body to the board of management, which oversees the integration of ESG factors into the business model, validates strategies/policies/methodologies/KPIs, and monitors the achievement of strategic objectives (NLB Group, 2024).

For the AI component, the report establishes board-level oversight through the Operations and IT Committee, with main tasks including monitoring AI use, integrating AI into operations, ensuring compliance with AI regulations, and overseeing key AI projects (NLB Group, 2024). In terms of data governance, the report shows the presence of structures such as the Data Governance Council and IT and product architecture committees, which identify and address the impact of ESG factors within their respective scopes (NLB Group, 2024).

NLB presents a model where AI-ESG integration is “institutionalized” through committees and policies: ESG is anchored in dedicated committees and reporting cycles, the Operations & IT committee with a clear mandate for compliance and accountability. This structure makes the case very suitable for comparative documentary analysis, because the “footprints” of integration are measurable in committee mandates, policy/KPI approval processes, and the way AI governance extends to operations and risk.

4.5 Raiffeisen Bank Kosovo (Kosovo) – Institutional integration of AI-ESG in a developing financial system

Raiffeisen Bank Kosovo primarily integrates ESG through its risk management and lending framework. The 2024 Annual Report links ESG risk appetite, risk management tools, data aggregation, reporting, and ESG integration into end-to-end processes, while also emphasizing the importance of measurement and analytical methodologies. Additional documentary evidence shows that ESG risks are incorporated into financing decisions through exclusion lists, employee training, ESG expert opinions for critical clients or projects, and procedures to prevent negative ESG impacts and greenwashing (Raiffeisen Bank Kosovo, 2022, 2024).

Compared with EU cases, AI-ESG integration at Raiffeisen Bank Kosovo appears more evident through ESG data collection, risk classification, and credit-process controls than through explicit references to advanced AI models. The documents indicate progress toward standardizing ESG definitions and collecting ESG data for larger corporate clients, but provide limited evidence of AI-based analytics embedded in core risk models or portfolio-level decision-making. This suggests that the bank is at an operational-reporting stage of ESG integration, where ESG is

increasingly linked to credit rules and risk processes, while deeper AI-enabled decision-making requires further empirical verification.

4.6 Thematic findings from deductive-inductive content analysis

The deductive-inductive content analysis identified four main themes: AI-enabled ESG data processing, ESG integration in financial decision-making, governance and oversight mechanisms, and institutional or structural constraints. In the deductive phase, the analysis focused on predefined categories derived from the literature, including AI integration, ESG indicators, risk management, governance structures, and decision-making processes. In the inductive phase, additional sub-themes emerged from the documents, including ESG data quality, proxy indicators, greenwashing prevention, limitations on external assurance, and the maturity gap between developed and emerging financial systems.

The first theme concerns AI-enabled ESG data processing. The findings indicate that the value of AI in ESG integration depends not only on analytical capacity but also on data quality, methodological transparency, and governance of uncertainty. For example, Nordea's use of PCAF-based financed-emissions methodologies and data-quality scoring illustrates how ESG data uncertainty can be managed through standardized procedures. Similarly, ING's reporting treats AI itself as a governance object, linking AI risks to privacy, accuracy, bias, accountability, and dedicated oversight structures.

The second theme focuses on ESG integration into financial decision-making. The evidence suggests that ESG becomes operationally relevant when it is embedded in lending procedures, client assessment tools, climate risk analysis, stress testing, and portfolio transition strategies. In the case of BNP Paribas, ESG questionnaires and climate risk assessment mechanisms illustrate how ESG indicators can serve as inputs to credit and monitoring processes rather than solely as reporting elements.

The third theme relates to governance and oversight mechanisms. The findings suggest that AI-ESG integration appears more credible and institutionally embedded when supported by committees, mandates, audit processes, model-risk controls, and data governance structures. NLB provides relevant evidence of this pattern, as its reports describe board-level and committee-level oversight of

sustainability, IT, and AI-related issues. This indicates that ESG and AI governance increasingly operate as interconnected elements within a broader control architecture.

The fourth theme captures institutional and structural constraints. Across the cases, data availability, regulatory complexity, methodological uncertainty, and external assurance limitations appear as key barriers to deeper AI–ESG integration. These constraints are present even in advanced banking systems, but they are more visible in emerging financial systems, where ESG data infrastructure and external verification mechanisms are still developing.

Table 2: Cross-Case Thematic Findings from Deductive - Inductive Content Analysis

Theme	Deductive Focus	Inductive Refinements Emerging from Documents	Illustrative Documentary Evidence (examples)	Cases where evidenced
Theme 1: AI-Enabled ESG Data Processing	ESG scoring automation; data integration; ML in risk analytics	Data-quality governance; uncertainty management; AI risk as a governance object	PCAF-based financed-emissions methodology with annual ALCO approval and PCAF data-quality scoring (1–5); dedicated AI oversight structures (AI Risk Committee, CoE)	Nordea; ING
Theme 2: ESG Integration in Financial Decision-Making	ESG in credit allocation; portfolio strategy; stress testing	ESG questionnaires as credit instruments; operational ESG “gatekeeping”; transition targets embedded in portfolio shifts	ESG questionnaires used in lending and linked to climate stress-testing logic; portfolio transition targets and reduced fossil exposure framing	BNP Paribas (Group / PL); (contextual implications for other cases)
Theme 3: Governance and Oversight Mechanisms	AI governance structures; model validation; transparency/compliance	Board-level AI oversight integrated with IT/security; sustainability	Supervisory Board Operations & IT Committee mandate: AI infrastructure/use, AI integration,	NLB

Theme	Deductive Focus	Inductive Refinements Emerging from Documents	Illustrative Documentary Evidence (examples)	Cases where evidenced
		reporting audit/controls ; double materiality engagement	responsibility, AI rules compliance; sustainability reporting process and external audit references	
Theme 4: Institutional and Structural Constraints	Data availability; regulatory pressure; capability gaps	Proxy use and residual uncertainty; compliance complexity; institutional verification limitations	Explicit treatment of uncertain/estimated ESG emissions data and proxies within PCAF framework; AI governance as response to risk/compliance constraints	Nordea; ING (with broader cross-case implications)

Source: Author's own elaboration based on qualitative document analysis using ATLAS.ti software

The fourth theme synthesizes the institutional and structural constraints that affect the intensity and quality of AI–ESG integration. A first constraint, also present in advanced banks, concerns the availability and quality of data, and documents acknowledge uncertainties and manage them through standardization approaches. At Nordea, the use of proxies and the assessment of data quality through the PCAF score make it clear that uncertainty is not completely eliminated; it is introduced into the methodology and reported as part of transparency. A second constraint is related to regulatory pressure and the complexity of compliance, which conditions the scaling of artificial intelligence by requiring control, demonstrability, and accountability. ING's reporting language, which treats AI risk as an object of governance and associates it with specific oversight structures, shows that the integration of AI into decision-making cannot be understood without the regulatory dimension and without the control of model risk. A third limitation, more pronounced in contexts with limited institutional capacities, relates to external verifiability and assurance infrastructure, which shifts integration towards the phases of database development, harmonized definitions, and consolidated control mechanisms.

In summary, the deductive–inductive content analysis suggests that AI–ESG integration is not a single technology product, but an institutional process that requires data governance, artificial intelligence governance, formalized decision-making instruments, and transparency mechanisms. The differences between cases appear more as differences in the maturity of the institutional architecture than as differences in declarations.

4.7 Cross-case comparative analysis: EU versus emerging financial system

The cross-case comparison suggests that the main difference between the EU banks and the Kosovo case lies not only in the level of technology use, but also in the institutional maturity of AI–ESG integration. In the EU, AI and ESG are more closely linked to risk management, lending procedures, portfolio monitoring, and governance structures. ING and NLB provide evidence of formal AI oversight and model-risk control, while BNP Paribas and Nordea illustrate how ESG data and climate-related indicators are incorporated into credit assessment, monitoring, and portfolio-level analysis.

In contrast, the Kosovo case reflects an earlier stage of integration, where ESG is mainly operationalized through data collection, exclusion lists, ESG expert opinions, greenwashing-prevention procedures, and reporting transparency. These mechanisms are important for institutional development, but the analyzed documents provide limited evidence of AI-based analytics embedded in core credit-risk models or portfolio allocation processes. This indicates a more compliance- and process-oriented form of ESG integration compared with the more formalized governance and analytical structures observed in the EU cases.

Overall, the comparison indicates that AI–ESG integration is deeper where ESG data infrastructure, AI governance, model-risk controls, and external assurance mechanisms are more developed. In emerging financial systems, the priority appears to be consolidating ESG data, standardizing internal procedures, and strengthening verification mechanisms before more advanced AI-enabled decision-making can be fully institutionalized.

Table 3: Cross-Case Comparison (EU Banks vs Kosovo Bank)

Comparative Dimension	EU Banks (ING, BNP Paribas, Nordea, NLB)	Kosovo Bank (Raiffeisen Bank Kosovo)
Depth of AI Integration	AI treated as a material risk and governance object; formal oversight and model-risk controls are emphasised; board/committee-level monitoring exists	Early-stage enablement through ESG data collection and process development; limited evidence of AI embedded in core risk models in the analysed reports
ESG Operationalization	ESG embedded into lending origination/monitoring via ESG assessment questionnaires; climate risk assessed within lending and linked to stress testing; portfolio-level emissions data consolidation and quality optimisation	ESG integrated through exclusion lists, ESG expert opinions for critical cases, and greenwashing-prevention steps; ESG data collection is being initiated
Governance Architecture	Formalised governance arrangements for AI oversight and compliance (committees, specialised structures); emphasis on governance and risk oversight linked to regulation	Governance and reporting are more compliance- and transparency-oriented; sustainability claims not externally assured in the analysed sustainability report

Source: Author's own elaboration based on qualitative document analysis and cross-case comparison. Coding and thematic categorization were performed using ATLAS.ti.

In EU banks, the governance architecture appears formalized and multi-layered, integrating board oversight, specialized committees, and control functions to manage AI and ESG risks. NLB provides direct evidence that AI governance is institutionalized through a board committee that monitors AI compliance, AI accountability, and AI integration into operations. ING similarly links the increased use of AI to the need for risk governance and oversight, citing specialized structures such as the AI Risk Committee and the Center of Excellence to strengthen control and governance. These elements suggest that in the EU, governance aims to manage not only compliance, but also model risk and automated decision risk, creating a stronger foundation for deep AI–ESG integration.

In the case of Kosovo, governance appears more oriented towards compliance and transparency in reporting, with a clear emphasis on capacity building and voluntary reporting. Raiffeisen Bank Kosovo's sustainability report states that sustainability performance data and claims have not undergone external assurance by an independent party, indicating that the external verification and audit architecture is still immature at this stage. From an analytical perspective, this reinforces the interpretation that the emerging system operates with a more

“compliance-based” governance, where internal policies, group rules, and ESG filters in financing are important, but where external assurance standards and the formalization of AI risk frameworks are less explicit in reporting.

4.8 Findings from process tracing: causal mechanisms

The process trace treats AI–ESG integration as a causal mechanism with five interconnected links: ESG data produces informative signals, which are processed through analytics and artificial intelligence, then translated into a risk assessment that conditions the financial decision, while the entire flow is overseen by the governance architecture. This approach makes it verifiable how reporting and digital capabilities are transformed into decision-making, as it seeks to identify the connections between the links and the points at which the institution intervenes.

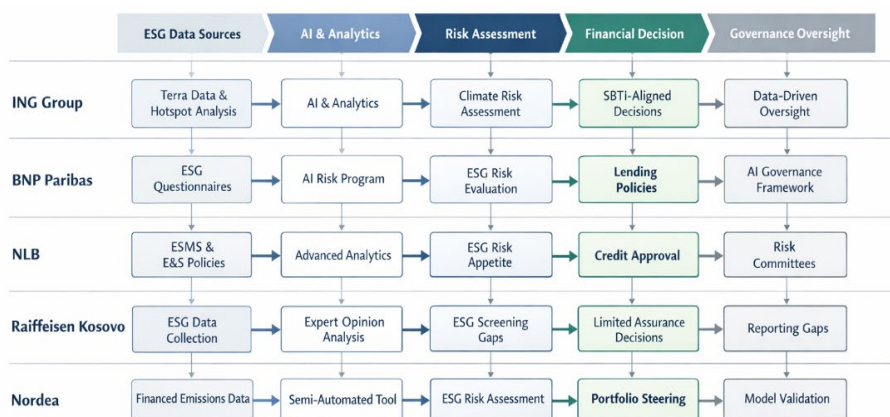


Figure 2: Process Tracing: Causal Mechanisms in AI – ESG Integration

Source: Author’s elaboration based on qualitative document analysis and process tracing

In the case of European Union banks, the mechanism appears generally more institutionalized. ESG data is organized according to internal methodologies and standards, while analytics and digital tools serve as institutional intermediaries that standardize data interpretation and link it to risk. Risk assessment, especially climate risk and model risk, appears to be integrated into lending policies and portfolio management, enabling more traceable financial decisions at the process level. Governance oversight is an integral part of this chain because committees and

control structures treat artificial intelligence and ESG as areas that require rules, accountability, and compliance, thereby strengthening the last link in the mechanism.

In the case of the emerging financial system, the mechanism is present, but often materializes through expert mediation and less automated processes. ESG data is in a consolidation phase, while analytics appears more as a capacity under construction than as an integrated layer in the basic risk models, while financial decisions rely on institutional filters such as exclusionary rules, reputational controls, and expert assessments for critical cases. Governance oversight is more oriented towards compliance and reporting transparency, which makes the mechanism functional for specific decisions, but less scalable at the full portfolio level.

Overall, tracing the process shows that the main difference between the EU and the emerging system lies not only in the presence of ESG or technology, but in the degree of institutionalization of the mediation between data and decision. In EU banks, the links are more closely connected through procedures, models, and committees; in the developing system, the links exist, but gaps appear more in the quality and coverage of data, in the formalization of analytics in risk assessment, and in the external verifiability of reporting.

4.9 Triangulation Analysis – Synthesis Method

The triangulated synthesis combines evidence from documentary analysis, cross-case comparison, and selective process tracing to develop analytically grounded interpretations of how ESG and artificial intelligence are integrated into banking decision-making. Figure 3 presents a synthesis of the triangulation of empirical findings, combining evidence from documentary analysis, cross-case comparison, and process tracing to draw analytical conclusions on the institutional mechanisms that influence the depth of AI and ESG integration in the banking sector.

The triangulated synthesis combines evidence from documentary analysis, cross-case comparison, and selective process tracing to develop analytically grounded interpretations of AI-ESG integration in banking decision-making. Figure 3 summarizes how ESG data, AI-enabled analytics, risk assessment, financial decision-making, and governance oversight are connected across the selected cases.

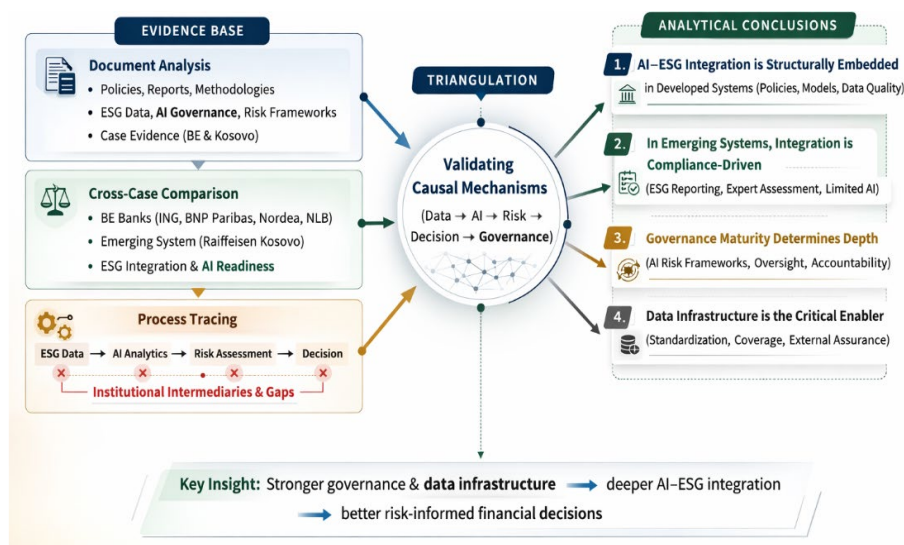


Figure 3: Triangulated synthesis of findings: AI – ESG integration in banking

Source: Author's elaboration based on qualitative document analysis, cross-case comparison, and process tracing of the selected banks

The triangulation suggests three main insights. First, in the EU cases, AI-ESG integration appears more structurally embedded in risk management and governance systems, supported by data-quality procedures, climate risk assessment tools, lending instruments, and committee-level oversight. Second, in the Kosovo case, integration appears more oriented toward compliance, ESG data development, exclusion mechanisms, and expert-based credit assessment, with more limited evidence of AI embedded in core decision-making models. Third, governance maturity is a key condition for deeper integration, as AI-enabled ESG decision-making depends on data quality, model risk controls, transparency mechanisms, and external assurance. Overall, the triangulated evidence suggests that the depth of AI-ESG integration depends less on the formal presence of ESG or AI and more on the institutional capacity to connect data, analytics, risk assessment, decision-making, and oversight.

5 Discussions

This study examined how artificial intelligence and advanced analytics are enabling the integration of environmental, social, and governance (ESG) factors into banking decision-making and the implications for sustainable governance in developed and

developing financial systems. The discussion below structures the interpretation of the findings around the research questions, then presents practical implications, limitations, and directions for future research.

First, in relation to the research question on how AI enables ESG integration, the findings suggest that the key role of AI lies not only in automation but in the ability to turn ESG data into usable signals for risk management and decision-making. In banks with well-developed systems, ESG data tend to be processed in a standardized manner and integrated into the data architecture and internal controls, making the link between measurement, analytical interpretation, and use in key processes such as lending, monitoring, and exposure management more stable. This strengthens the argument that AI–ESG integration is a socio-technical transformation, in which technology has a real effect only when supported by institutional process design and data governance.

Secondly, regarding the research question on the impact of ESG on financial decision-making, the findings show that ESG is most operationalized when embedded in concrete decision-making instruments, such as lending policies, climate risk assessments, stress tests, and portfolio repositioning. In this context, ESG appears not only as a reporting framework but also as a criterion for capital allocation and for controlling exposures to transition and physical risks. In contexts with more limited capacity, ESG tends to be operationalized initially through protective filters, such as exclusion lists, reputational checks, and expert assessments, which influence the financial decision but make it more difficult to scale integration to the portfolio level.

Third, regarding the research question on governance and regulatory challenges, the study finds that governance maturity is a determinant of the depth of integration. In developed systems, AI and ESG governance tends to be formalized in dedicated structures, committee mandates, model risk controls, and transparency and compliance requirements. This reduces the likelihood that AI will be used opportunistically or solely for efficiency because it places the technology within a framework of accountability, audit, and control. In developing systems, governance appears more oriented towards compliance and reputational risk management, while the main challenge remains strengthening verifiability and increasing institutional

capacity to manage model risk and to ensure transparency in decision-making assisted by analytics.

Fourth, in relation to the research question on the differences between the EU and the developing system, comparative analysis and process tracing show that the main difference is not simply the “presence of AI” or the “presence of ESG”, but the way in which the links of the mechanism are connected from data to financial decision and supervision. In developed systems, the links tend to be more connected and institutionalized, making the mechanism more stable and traceable. In developing systems, the mechanism exists, but often relies on expert mediation and data consolidation phases, which produce gaps in standardization, analytical scalability, and verifiability.

The findings provide practical implications for both bank managers and policymakers, particularly when interpreted in light of the study’s documentary and comparative design. For bank managers, the results suggest that AI–ESG integration should be treated as an institutional capability rather than only as a technological initiative. This requires standardizing ESG data, systematically documenting data quality, integrating ESG indicators into lending and portfolio processes, and developing clear AI governance mechanisms. Banks should strengthen model risk management, validation procedures, bias monitoring, transparency protocols, and internal audit mechanisms, especially where AI-supported tools influence credit assessment, risk classification, or capital allocation. In emerging financial systems, bank managers should prioritize consolidating ESG data infrastructure, staff training, developing internal ESG taxonomies, and gradually integrating ESG indicators into credit and risk management processes.

For policymakers and regulators, the findings indicate the need to develop clearer standards for ESG data comparability, AI transparency, model risk governance, and external assurance of sustainability-related disclosures. Regulatory frameworks should encourage banks to move beyond formal ESG reporting toward operational integration of ESG factors into risk management and financial decision-making. In emerging financial systems, particular attention should be given to institutional capacity-building, supervisory guidance, digital infrastructure, and minimum disclosure requirements for AI-supported financial decisions. Such measures would help reduce the risk of superficial compliance, strengthen accountability, and

support a more credible transition toward sustainable and digitally enabled banking governance.

A key limitation of this study relates to its reliance on publicly available documentary sources, including annual reports, ESG reports, sustainability disclosures, risk management documents, and governance reports. Although these sources provide valuable evidence on how banks formally report, structure, and communicate AI–ESG integration, they do not allow direct observation of internal decision-making processes, model-level implementation, or managerial interpretations. As a result, the findings should be interpreted as analytically reconstructed patterns of reported institutional practices rather than as direct verification of operational AI use in lending, risk assessment, or portfolio allocation. This limitation is particularly relevant because banks may disclose AI and ESG practices selectively, depending on regulatory requirements, reputational considerations, and the level of transparency in public reporting. Therefore, the analysis may either underestimate actual internal practices that are not publicly disclosed or overestimate integration where strategic reporting is stronger than operational implementation. While methodological triangulation, cross-case comparison, and selective process tracing strengthen the analytical consistency of the study, further empirical validation would require access to internal bank documents, model validation reports, lending policies, risk committee materials, and interviews with risk, compliance, sustainability, and data analytics managers. Future research should therefore combine documentary analysis with primary qualitative evidence and, where possible, internal operational data to assess more precisely the depth, effectiveness, and governance quality of AI-enabled ESG integration in banking decision-making.

Future research could also test which governance configurations (committees, mandates, audit, and external assurance) are most effective at reducing model risk and increasing transparency in AI-assisted decision-making. Another important direction is to analyze the impact of data infrastructure quality and ESG indicator standardization on banks' ability to move from reporting compliance to operational and strategic integration.

6 Conclusions and Recommendations

This study suggests that AI-enabled ESG integration in banking decision-making should be understood not only as a technological development, but also as an institutional and governance process. The findings indicate that, in more developed financial systems, AI and ESG are more visibly embedded in risk management, lending, portfolio monitoring, and governance structures. In contrast, the case from an emerging financial system shows a more gradual form of integration, mainly focused on ESG data collection, reporting, compliance mechanisms, exclusion rules, and expert-based credit assessment.

The comparative analysis and selective process tracing provide evidence that the depth of AI–ESG integration depends on the institutional capacity to connect ESG data, AI-enabled analytics, risk assessment, financial decision-making, and governance oversight. When these links are supported by data-quality procedures, model risk controls, committee-level supervision, and transparency mechanisms, AI–ESG integration appears more traceable and operationally relevant. Where such mechanisms remain less developed, integration tends to be more fragmented and less scalable across core banking processes.

The study offers several recommendations. Banks in developed financial systems should further strengthen AI governance, model validation, bias monitoring, internal audit, and transparency protocols, particularly when AI-supported tools influence credit, risk, and portfolio decisions. Banks in emerging financial systems should prioritize developing ESG data infrastructure, standardized classification systems, staff training, external assurance, and the gradual incorporation of ESG indicators into lending and risk management processes. For regulators and policymakers, the priority should be to establish clearer standards for ESG data comparability, AI transparency, model risk governance, and sustainability disclosure assurance.

Overall, the study contributes to the literature on sustainable finance, digital transformation, and banking governance by showing that effective AI-ESG integration depends less on the formal adoption of AI or ESG reporting and more on the quality of institutional mechanisms that transform data into accountable financial decision-making. Future research should extend this analysis through

interviews, internal banking documents, and model-level evidence to validate the operational depth of AI-enabled ESG integration across different financial systems.

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NAVIGATING BETWEEN ENVIRONMENTAL AND SOCIAL SUSTAINABILITY: DIFFERENT PATHS OF EU ELECTRICITY PRODUCTION TRANSFORMATION AND THEIR IMPACT ON HOUSEHOLD CONSUMERS ELECTRICITY PRICES

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The phase-out of asbestos in urban environments represents a complex challenge across European municipalities. Despite European Union targets to achieve asbestos-free cities, implementation remains uneven because municipalities face fragmented regulations, differing inspection and disclosure requirements, limited funding, technical constraints, and variable public awareness. The paper identifies key barriers, including regulatory heterogeneity, inadequate disposal infrastructure, financing gaps, and institutional coordination challenges, alongside enabling factors such as harmonized policies, innovative treatment technologies, capacity-building programs, community engagement, and transparent governance. Based on these insights, a typology of municipal transition pathways is developed, including compliance-driven, retrofit-integrated, innovation-led, community-driven, and market-based approaches. The findings underline equity considerations, emphasizing the need to prevent disadvantaged communities from remaining disproportionately exposed to asbestos hazards. By framing asbestos removal as a material legacy transition within broader urban sustainability transitions, the paper contributes to theoretical understanding of socio-technical and ecosystem dynamics while offering practical guidance for policymakers, urban planners, and other stakeholders seeking resilient, equitable, and sustainable asbestos-free municipalities across Europe. It also highlights the importance of integrated governance, long-term financing, systematic monitoring, knowledge sharing between municipalities, stakeholder collaboration, regulatory consistency, public communication, workforce training, and continuous policy learning to accelerate safe, effective, scalable implementation across diverse European regions sustainably.

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1 Introduction

Modern society is fundamentally dependent on electricity, with a trend accelerated by the proliferation of digital devices, automated systems, and smart technologies that enhance comfort and efficiency for people and industrial entities. This dependence ranges from automated home management (such as lighting and climate control) to large-scale societal changes like the adoption of electric vehicles. Globally, there was a 2.66-fold increase in global electricity consumption from 10,243 TWh to 27,246 TWh over the period from 1990 to 2024, and it is expected to rise to 64,513 TWh by 2050, reflecting an estimated annual growth rate of 3% (Gvozdenac et al., 2025). This increase is primarily attributed to steady economic growth, high demand from industry due to the ongoing shift towards greater automation, digitalisation, rising electric vehicle charging, use of artificial intelligence (AI), and consequently new data centres and increased cooling needs to run AI (Enerdata, 2025). Vries (Vries, 2023) asserts that Google search utilises 10 times less energy than ChatGPT search and 13.8 times less energy than Bloom search.

As global electricity demand increases, new, more efficient, and sustainable technologies need to be implemented. Sustainable electricity entails generating power in an environmentally responsible way, minimizing environmental impact, and addressing long-term resource availability (Electric, 2023). Renewable energy sources, including wind, solar, geothermal, hydropower, bioenergy and tidal energy, are categorised as sustainable and environmentally acceptable technologies (IEA, 2025).

The European Commission has systematically changed and tightened energy policy with the primary goal of reducing greenhouse gas (GHG) emissions. This supports European Green Deal commitments to reduce GHG emissions by at least 55% by 2030 and become climate neutral by 2050 (European Commission, 2019). In 2007, the European Union (EU) set three key targets for 2020: (a) a 20% cut in GHG emissions compared to 1990 levels; (b) a 20% increase in EU renewable energy; and (c) a 20% improvement in energy efficiency (European Commission, 2009). The Renewable Energy Directive (European Commission, 2009) and REPowerEU Plan (European Commission, 2022) were developed to achieve an affordable and

environmentally acceptable EU energy supply. Current targets include a 11.7% reduction in final energy consumption by 2030 relative to the 2020 projection (European Commission, 2025) and increasing the share of renewables in the energy mix to at least 42.5% by 2030 (European Commission, 2023a). Policy efficiency and sustainability outcomes are strengthened by integrated policy design rather than fragmented programs, which result in high costs and duplication of efforts (Colombo, 2025).

EU countries are implementing different approaches to achieve those EU targets, and their levels of success vary significantly. Therefore, this study provides an overview of different approaches across EU countries and evaluates their success in the transition toward sustainable electricity production.

2 Literature review

In the literature, the energy sector is widely examined from different points of view. Many studies have focused on countries' natural resource endowments and the availability of renewable sources. Bessin et al. (Bessin et al., 2025) examined the potential for implementation of specific technologies in the EU and highlighted that the countries with the highest wind turbine potential include Denmark, Ireland, the Netherlands, Belgium, northern Germany and France. Areas with significant potential for solar photovoltaic have been identified in the Netherlands, Germany, flat regions in Italy, southern and central Spain, Poland, the Czech Republic, and Hungary. However, considerable variation remains among countries, due to the uneven distribution of renewable resources, which depends heavily on a country's geographical location and natural resources.

Studies have also focused on the environmental perspective of electricity production evaluating the correlation between the adoption of renewable energy sources and the mitigation of GHG emissions. For example, Bilan et al. (Bilan et al., 2019), examined the interrelationship between GDP, renewable energy, and emissions, concluding that economic growth is associated with increased energy consumption from renewables. Contrastingly, Gao et al. (Gao et al., 2026) indicate that a high reliance on natural resources significantly undermines the financial sustainability in the long term, which confirms the resource curse theory. Moreover, producing

energy only from the renewable sources until 2050 is not realistic, while renewable electricity could contribute only up to 44% of Europe's primary energy consumption mix by 2050 under the most ambitious policy scenarios (Salim et al., 2026).

While some of the scientific papers are mainly related to economic factors and the growth and share of electricity produced from renewable sources, others focus more on the environmental impacts associated with energy from renewable sources. Fajdetić and Festić (Fajdetić & Festić, 2022), studied the role of solar energy and solar systems in reducing GHG emissions in the EU for the period from 2010 to 2020, concluding that solar energy has a statistically significant impact on GHG emissions reduction. Schürmann (Schürmann, 2024) examined the correlation between reference market selection for real-time electricity tariffs and the emissions associated with electricity procurement. He concluded that there is no advantage in associated carbon emissions for the intraday market over the day-ahead market, even when carbon intensity is factored into the optimisation. While other authors focused on energy in general, Rybaczewska-Błażejowska and Jezierski (Rybaczewska-Błażejowska & Jezierski, 2024) focused only on electricity and conducted life cycle assessment of the environmental impacts caused by different electricity mixes, analysing the electricity consumption mixes of EU countries and highlighting the importance of selecting the right life cycle impact assessment (LCIA) method.

Based on the literature review, the authors mostly evaluated only one aspect of sustainability and are focused on the energy sector rather than electricity specifically.

In addition to the aforementioned parameters, energy source dependency and security must be considered as strategic aspects of the energy sector. Muhammad et al. (Muhammad et al., 2025) found that energy diversity and energy dependency risk contribute significantly to electricity prices, while geopolitical risk shows no significant direct effect. However, the interaction between energy dependency and geopolitical risk was found to increase electricity prices (Muhammad et al., 2025).

This study evaluates electricity production in EU countries from environmental and economic point of view. It examines the interrelationship between the share of renewables in the electricity production mix and household electricity prices, especially if a higher share of renewable electricity decreases the household electricity

prices as foresighted by EU. Additionally, since specific empirical studies, which quantify the extent to which the transition to renewable electricity has succeeded in reducing GHG emissions and total environmental impacts, this study provides an analysis of environmental performance for national electricity mixes from 2003 to 2023.

3 Methodology

3.1 Eu countries efficiency assessment

In the assessment of efficiency regarding the EU Commission goals to achieve climate neutrality by 2050, a two-decade period was considered to determine the trend of replacing fossil-based electricity production technologies with renewable ones. The study focusses solely on EU countries where data on electricity production by specific technology are available for the period from 2003 to 2023. The year 2023 was selected as the end year, as data for 2024 and 2025 are currently unavailable. The electricity production data are based on the IRENA database, a leading intergovernmental agency for energy transformation that serves as the principal platform for international cooperation, supports countries in their energy transitions, and provides state of the art data and analyses on technology, innovation, policy, finance and investment (IRENA, 2025a). Electricity generation data from the IRENA database (originally in GWh) were converted into percentage shares (%) to reflect the specific technology mix analysed in this study. Shares of renewable sources in the electricity production mix were calculated using Equation 1.

$$s_i = \frac{E_i}{\sum_{i=1}^n E_i} \cdot 100 \quad (1)$$

Where:

i – electricity production technology [/]

s_i – share of produced electricity with specific technology i [%]

n – number of all electricity production technologies [/]

E_i – amount of produced electricity with specific production technology i [GWh]

3.2 EU countries economic data acquisition

The data on household electricity prices were obtained from two Eurostat databases. The first database contains bi-annual data up to 2007 (Eurostat, 2021), and the second database contains bi-annual data from 2007 onwards (Eurostat, 2025). This study incorporates electricity prices excluding and including taxes and levies, separately, thereby providing a clearer perspective on how a countries' taxation and incentives influence the final household electricity prices.

3.3 Life cycle assessment (LCA)

The environmental performance of electricity mixes was calculated using the LCA method, with a special focus on global warming impacts and total environmental impacts. The LCAs were performed in accordance with the international standards ISO 14040 (*ISO 14040*, 2006) and ISO 14044 (*ISO 14044*, 2020).

The goal and scope:

The goal of this study was to quantify the total environmental and global warming impacts of specific national electricity mixes. For this purpose, a cradle-to-gate life cycle assessment was conducted. The environmental part of the study evaluated Slovenia alongside the four EU countries demonstrating the highest growth in renewable electricity generation (Denmark, Germany, Lithuania, and the Netherlands). Environmental impacts were assessed annually for each country over the period from 2003 to 2023. The functional unit was defined as 1 MJ of electricity produced using a specific mix of technologies.

Life cycle inventory analysis (LCI):

Data collection was based on available electricity generation shares by technology from the International Renewable Energy Agency (IRENA) database (IRENA, 2025b). Secondary background data were sourced from Ecoinvent 3.11 database (Ecoinvent Association, 2023), which encompasses more than 26.000 peer-reviewed datasets. This database was selected for its country-specific datasets, enabling comprehensive environmental reporting and sustainable decision-making.

Life cycle impact assessment (LCIA) phase:

To characterise the environmental impact profile of the national electricity mixes, two LCIA methods were used. Global warming impact category was quantified using ReCiPe 2016 Midpoint from hierarchist perspective (H), whereas the total environmental impact was calculated using ReCiPe 2016 Endpoint (H). Although the ReCiPe 2016 Endpoint (H) method also supports global warming calculations, the ReCiPe 2016 Midpoint (H) method was selected to ensure results expressed in kg CO₂ eq rather than in Ecopoints (Pt). The assessment was conducted in SimaPro software (version 10.2.0.3 Analyst).

The life cycle results interpretation:

The LCA results were collected and analysed for the five selected EU countries (Denmark, Germany, Lithuania, the Netherlands and Slovenia) over the same time frame and electricity output capacity. These results are discussed regarding both global warming and total environmental impacts (Figure 3).

3.4 Pearson correlation coefficient

Considering only the growth of renewable electricity and its associated environmental mitigation does not provide the full socio-economic complexity of the electricity transition. From a consumer standpoint, price remains a primary determinant in decision-making; consequently, this assessment also integrates economic indicators alongside environmental ones. Specifically, the relationship between the share of renewable electricity and household electricity prices was evaluated to determine whether a correlation exists. It is imperative to acknowledge that a correlation expressed by Pearson's coefficient does not inherently imply a causal relationship; consequently, the interpretation of results should be conducted with caution.

For the EU member states, the strength of the relationship between household electricity prices excluding taxes and levies; and the share of electricity generated from renewable sources was analysed using the Pearson correlation coefficient. While the first calculation of Pearson correlation coefficient excludes taxes and

levies, additional calculation was conducted using household electricity prices including taxes and levies, to evaluate the impact of taxes and levies on the Pearson correlation coefficient values. While the price does not depend only on taxes and levies, it can also be influenced by other national measures such as subsidies and social transfer mixes, meaning the Pearson correlation coefficient results cannot be used as the definitive and sole interpretation of the connection between household electricity prices and the share of renewable electricity in the national mix.

The Pearson correlation coefficient was calculated for each country using annual data on household electricity prices (in € per kWh) and data regarding shares of renewable sources in electricity production mix (in percentage) for the period from 2003 to 2023. The calculation employed the standard computational formula for Pearson correlation coefficient as shown in Equation 2 (Lane et al., 2018).

$$r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \quad (2)$$

Where:

r – Pearson correlation coefficient

x – household electricity price excluding taxes and levies or household electricity price including tax and levies

y – share of electricity produced from renewable sources

The analysed countries were aggregated into seven distinct groups based on comparable trends in the growth of renewable electricity. For each individual country, a specific Pearson correlation coefficient was first calculated and further averaged within each group of countries.

4 Result and discussion

4.1 Trends of electricity production from renewable sources in eu countries

Under the REPowerEU Plan, EU Member States are required to increase the share of renewables sources in their energy mixes to binding target of at least 42.5% by 2030 (European Commission, 2023a), and to achieve climate neutrality by 2050 (European Commission, 2019). To evaluate national progress toward these EU goals, this study analyses renewable electricity production trend from 2003 to 2023. Based on the national data, EU countries can be categorised into two distinct groups: (a) countries with a moderate (linear regression curves with comparable slopes) increase of electricity production from renewable sources in the national electricity production mix (Figure 1a) and (b) countries with a significant (non-linear shape) increase of electricity production from renewable sources in the national electricity production mix (Figure 1b). If the countries could be described with both the linear regression curves, the slopes would be greater than those for the group of countries with moderate increase. Additionally, the countries with a moderate increase were divided into four groups, where the countries with a similar starting and ending share of renewables in the electricity mix were combined. On Figure 1a only the most representative country from each group of countries is presented.

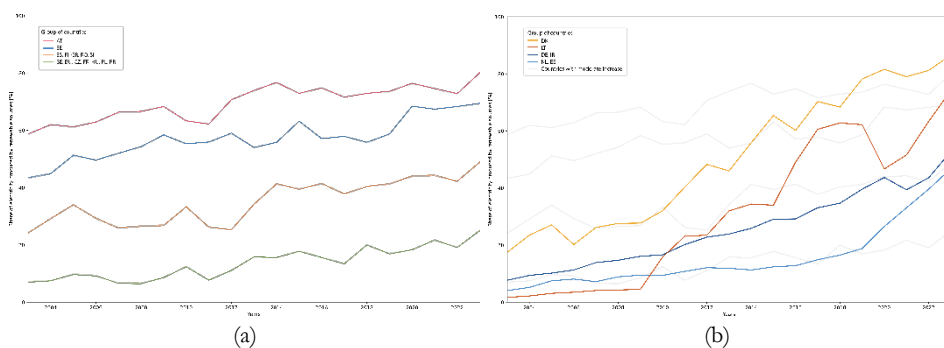


Figure 1: Comparison of electricity integration from renewable sources in the national electricity mix (2003 – 2023): (a) countries with a moderate progress, (b) countries with a significant increase in renewable electricity integration.

Source: Based on International Renewable Energy Agency (IRENA) database (IRENA, 2025b).

Most of the EU countries took a moderate approach, characterised by a steady, incremental increase in the share of renewables in their electricity mixes. As illustrated in Figure 1a, the four groups of countries have a similar growth pattern, with a linear regression curve slope of approximately one, despite variations in their initial baseline shares of renewables in the electricity mixes. On average, these countries increased production of renewable electricity by 27.28 percentage point (p.p.) over the two-decade period.

Certain countries were even more effective and responsive in implementing the EU's long-term strategy to reach 45% share of energy from renewable sources in the EU's gross final energy consumption by 2030, as outlined in the Renewable Energy Directive (RED) (European Commission, 2023a). Lithuania (72.5 p.p.), Denmark (69.1 p.p.), Germany (45.1 p.p.) and the Netherlands (42.7 p.p.) have increased their production of renewable electricity most significantly (Figure 1b). Two distinct growth patterns are evident among these four nations: (a) a consistently high increase in electricity from renewables with a regression slope of approximately 3.8, for Denmark and Lithuania, and (b) an initial moderate phase followed by accelerated growth in the second decade, resulting in a regression slope of approximately 1.7, as seen in Germany and the Netherlands. These four countries were selected for an in-depth analysis due to their demonstrated leadership in the transition from non-renewable to renewable electricity generation within the study of EU member states.

Over the past two decades, Denmark, for example, has reduced its share of fossil fuels in its electricity production mix by 69.1 p.p. (Figure 2), while significantly increasing the contributions of wind (45.5 p.p.), bioenergy (13.7 p.p.), and solar (10.0 p.p.). This rapid transition has been driven by ambitious national goals to achieve 100% renewable energy supply by 2050 (Hvelplund & Djørup, 2017). Denmark has focused primarily on expanding its wind energy infrastructure, with a strategic goal to increase offshore wind capacity sevenfold by 2030 (International Energy Agency, 2023). This commitment persists despite research by Ryu and Sovacool (Ryu & Sovacool, 2025), which indicated that cost overruns for offshore wind facilities are increasing annually, in contrast to decreasing overruns for onshore wind facilities. Research by Lund et al. (Lund et al., 2022) concludes that the Denmark's ambitious national targets are achievable within the constraints of its global share of biomass resources, by structural transformation of the energy sector

from centralised systems to a decentralised structures owned by municipals or cooperatives (Pinson et al., 2017).

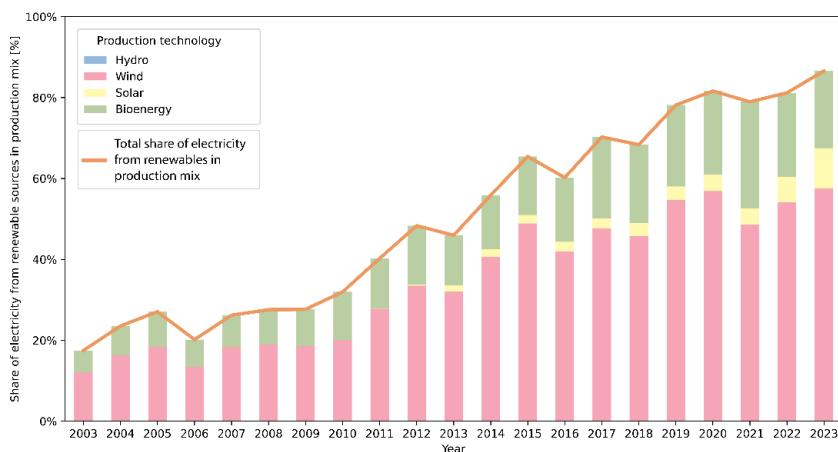


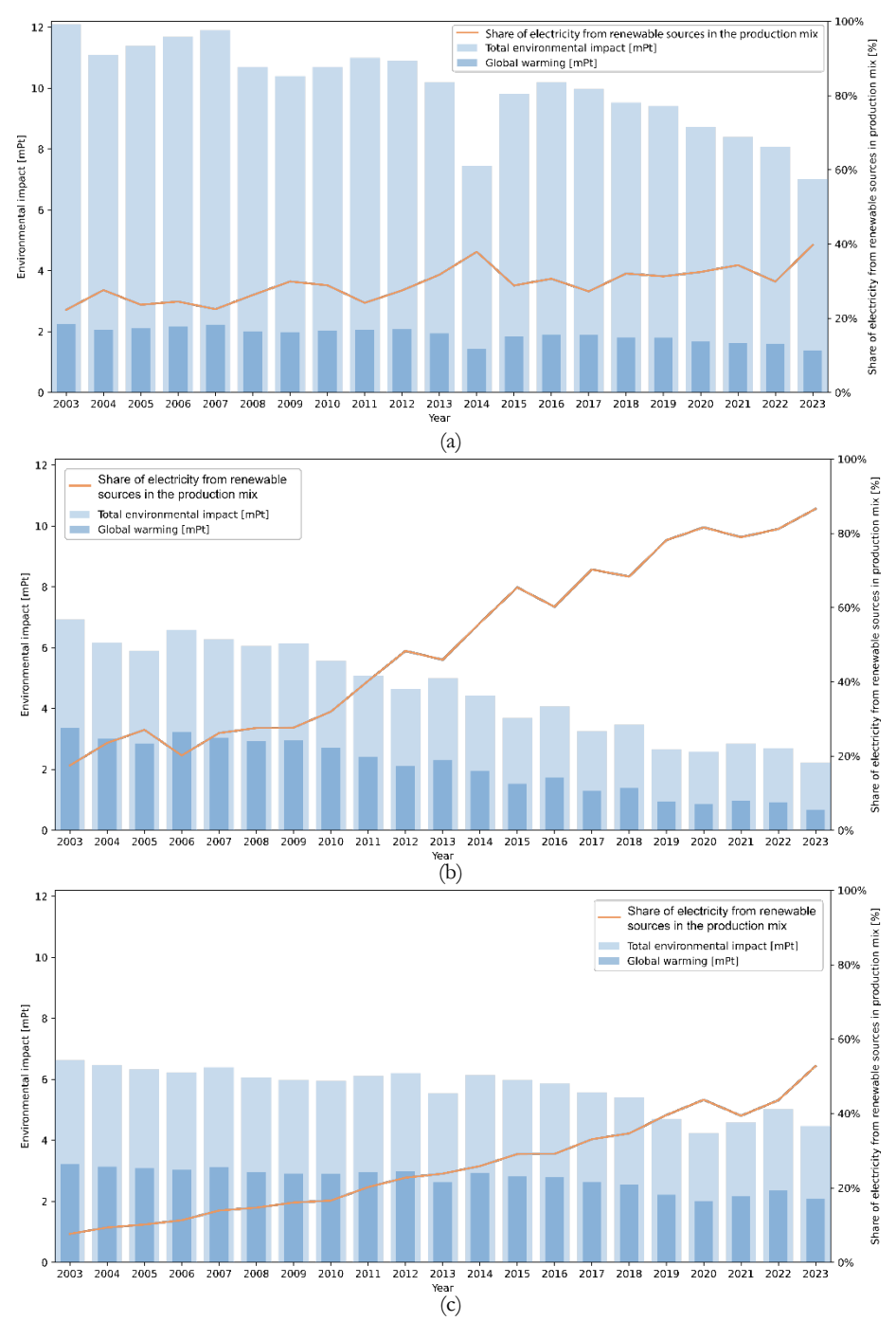
Figure 2: Share of electricity from renewable sources within the Danish electricity mix (2003 – 2023), disaggregated by production technology.

Source: Based on International Renewable Energy Agency (IRENA) database (IRENA, 2025b).

4.2 Environmental impacts of national electricity production mixes

While EU Member States have successfully reduced their dependency on non-renewable energy technologies, this trend does not inherently reflect a decrease in environmental impacts. To meet the European Green Deal commitments, EU countries must adhere to established GHG reduction targets and achieve climate neutrality by 2050 (European Commission, 2019). Consequently, the environmental impacts associated with the electricity production for Slovenia and countries with the highest growth in renewable electricity (Denmark, Germany, Lithuania and the Netherlands) for the period from 2003 to 2023 were considered.

The environmental burdens per 1 MJ of generated electricity were quantified for each year from 2003 to 2023 employing the ReCiPe 2016 Endpoint (H) method. Only the global warming impact category, which provides information on GHG emissions, and the total environmental impact were considered and compared against the share of renewable electricity in selected countries.



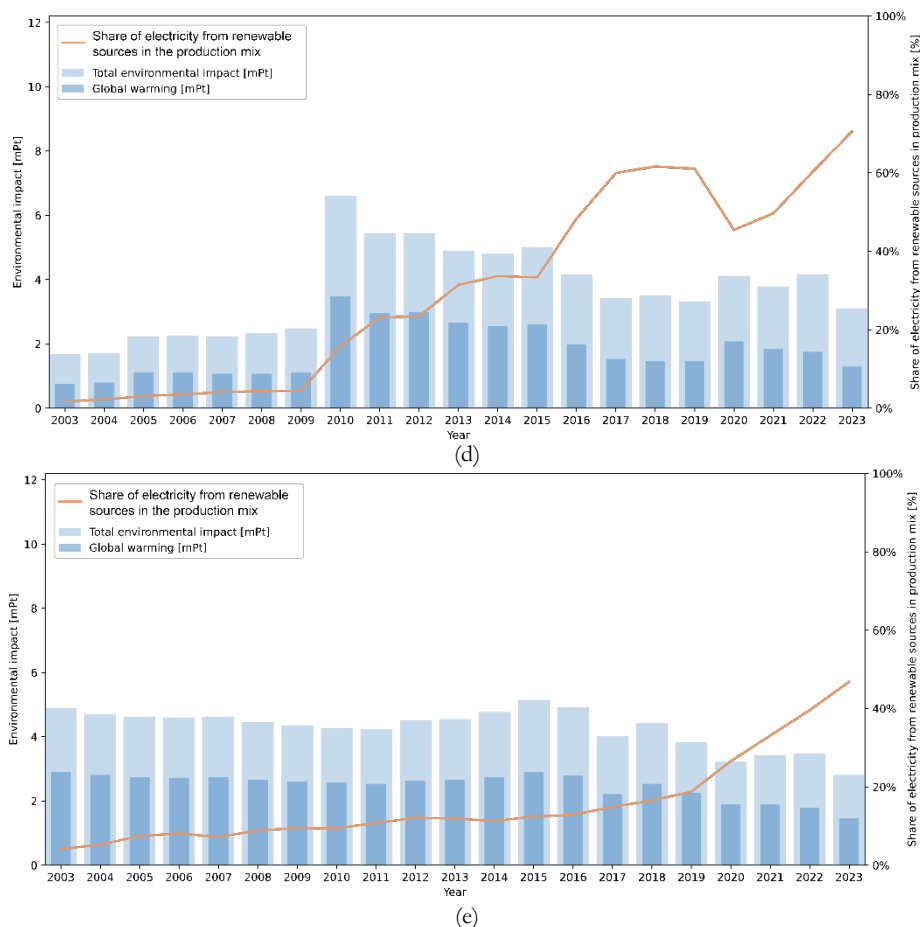


Figure 3: Share of electricity from renewable sources (orange) and environmental impacts of electricity mix (2003 – 2023), based on the ReCiPe 2016 Endpoint (H) method. Global warming impact category (dark blue) and total environmental impact (light blue) are expressed in ecopoints [Pt] for: (a) Slovenia, (b) Denmark, (c) Germany, (d) Lithuania and (e) Netherlands.

Source: Share of renewable electricity based on International Renewable Energy Agency (IRENA) database (IRENA, 2025b), while environmental impact are based on the calculations using SimaPro software (Pré Sustainability, 2024).

Figures from Figure 3a to Figure 3e present the correlation between the share of electricity from renewable sources in electricity production mix and environmental performance, with light blue presenting total environmental impact and dark blue indicating global warming impact category.

Among all evaluated countries, the Slovenian electricity mixes have the highest environmental impacts and the largest differences between total environmental and global warming impacts (Figure 3a). This indicates that the technologies used in Slovenia exert a greater influence on the impact categories such as particulate matter and ionizing radiation, rather than on global warming. While global warming accounts for majority share of the total environmental impact in all other evaluated countries, its contribution in Slovenia is limited to approximately 20% of total environmental impact.

Despite the marginal growth in renewable electricity share from 22.3% to 39.7% (17.4 p.p. in total) depicted in Figure 3a, Slovenia managed to decrease absolute values of the total environmental impact caused by its electricity production mix the most. Specifically, over the period from 2003 to 2023 the total environmental impact has decreased from 12.10 mPt to 7.02 mPt per MJ of produced electricity (for 5.08 mPt per MJ). In comparison, Denmark decreased its total environmental impact from 6.93 mPt to 2.22 mPt per MJ (for 4.71 mPt per MJ), Germany from 6.63 mPt to 4.47 mPt per MJ (for 2.16 mPt per MJ) and the Netherlands from 4.89 mPt to 2.81 mPt per MJ (for 1.43 mPt per MJ). The only exception is Lithuania, where the total environmental impact increased from 1.68 mPt to 3.11 mPt per MJ (for 1.43 mPt per MJ) with the implementation of renewable electricity.

Regarding the reduction of global warming impacts, Denmark was the most successful country with the reduction from 3.38 mPt per MJ to 0.67 mPt per MJ (equal to 0.167 kg CO₂ eq per MJ of produced electricity mix). Decrease was also recorded in the Netherlands where global warming impacts have decreased from 2.90 mPt to 1.47 mPt (equal to 0.088 kg CO₂ eq), in Germany from 3.22 mPt to 2.08 mPt (equal to 0.071 kg CO₂ eq) and in Slovenia from 2.26 mPt to 1.37 mPt (equal to 0.054 kg CO₂ eq). Conversely, Lithuania increased its impact on global warming from 0.76 mPt to 1.29 mPt (equal to 0.033 kg CO₂ eq).

Lithuania recorded the largest increase in its share of renewable electricity (by 72.5 p.p.), leading to significant increase of both overall environmental impact as well as global warming. The most notable change occurred in 2010 by a transition from nuclear power to mostly fossil fuels, which are less environmentally acceptable, and partially with the renewable sources (IRENA, 2025b). However, from 2010

onward, Lithuania began reducing its reliance on fossil fuels by mostly replacing them with wind energy, resulting in significant increase in the renewable electricity share and decrease in environmental impacts. Despite the upward trend in renewable energy integration in Lithuania's electricity mix, renewable energy share declined substantially in 2020. Unstable hydrological conditions necessitated a compensatory reliance on fossil fuels, with the deficit primarily addressed through natural gas- fired power generation (IEA, 2021).

4.3 Correlation between household electricity price and share of renewable sources in electricity production mixes

Evaluating whether an increase in renewable electricity is sustainable cannot be based solely on numerical values for shares of produced electricity from renewables, which are generally associated with a lower price, nor on the environmental pillar of sustainability. Additionally, from an economic perspective more economic indicators need to be considered, specifically how the transition in production technologies affects the final consumer. By addressing these two pillars of sustainability, a more comprehensive assessment can be made of whether an increase in renewable electricity is truly more sustainable.

In this study, the economic pillar of sustainability was based on household electricity prices with and without taxes and levies. Two types of household electricity prices were considered to gain a better view of how a country's subsidies and taxation influence the electricity price.

Figure 4 presents household electricity prices in Denmark for the period from 2003 to 2023, where blue dots show the prices without tax and levies, while orange dots show the prices with tax and levies.

Household electricity prices, both with and without tax and levies, differed over the period from 2003 to 2023, with major changes in 2008 and 2022. In 2008, Phase II of the EU Emissions Trading System (ETS) began, with the EU setting a cap on carbon emissions and allowing the trading of emissions allowances (Dormady & Englander, 2016). Since then, countries have systematically incorporated carbon prices into wholesale electricity prices, effectively shifting the financial burden onto

end consumers (Freitas & Silva, 2015), who ultimately pay the price for carbon emissions despite having no direct control over the electricity mix. Ahmada and Kirat (Ahamada & Kirat, 2015) further confirmed that Phase II of the EU ETS had an impact on the power-generation sector in France and Germany, leading to much higher household electricity prices.

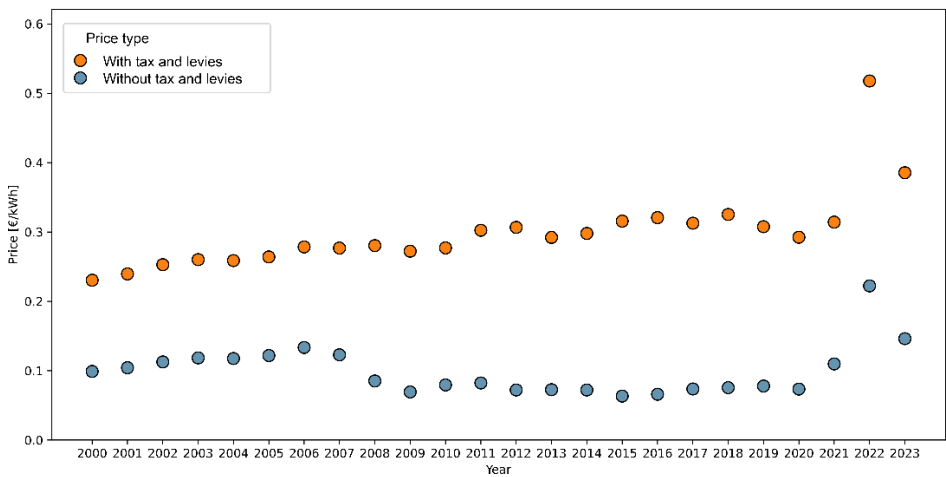


Figure 4: Evolution of Danish household electricity prices (2003 – 2023) with (orange) and without (blue) tax and levies.

Source: Based on Eurostat database (Eurostat, 2021; Eurostat, 2025).

In 2022 an energy crisis led to an unprecedented spike in EU electricity prices, as record-high natural gas prices and major cuts in Russian pipeline supply (Goldthau & Youngs, 2023) pushed wholesale power benchmarks in the third quarter of 2022 to around 339 € per MWh (European Commission, 2023b). To mitigate the socio-economic impact, several EU countries such as Belgium, Finland, Germany, Lithuania and the Netherlands implemented temporary reduction in electricity taxes and levies, while Austria, France, Hungary, Spain, and Slovenia set the electricity price cap (Arregui, 2022; Galgóczi, 2023), to shield households from the full extent of the market volatility.

Household electricity pricing is not only contingent upon annual inflation and country regulatory frameworks but is also driven by the cost-efficiency of the electricity generation technologies. Figure 5 presents Danish household electricity

prices with (orange) and without (blue) tax and levies in correlation with the share of electricity from renewable sources in the Danish electricity mix.

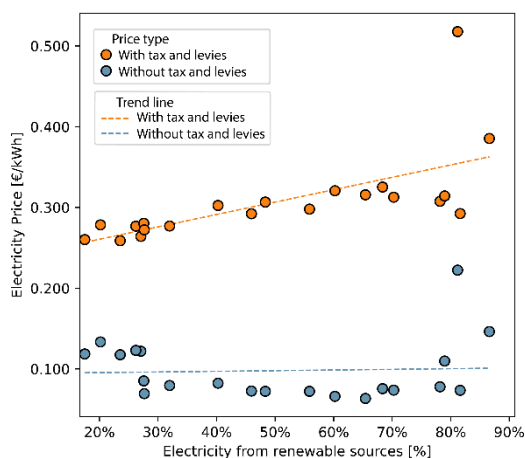


Figure 5: Correlation between Danish household electricity price and share of electricity from renewable sources in Danish electricity mix (2003 – 2023). Orange marks present prices with tax and levies, while blue marks present prices without tax and levies, with corresponding regression lines (dashed lines).

Source: Electricity prices are based on Eurostat database (Eurostat, 2021; Eurostat, 2025), while share of electricity from renewable sources is based on International Renewable Energy Agency (IRENA) database (IRENA, 2025b).

In Denmark, household electricity prices generally decreased as the share of renewable electricity increased, consistent with current Levelized Cost of Energy (LCOE). According to Lazard’s analysis (Lazard, 2025), renewable generation remains more cost-competitive than conventional generation; utility-scale solar photovoltaic (38–78 \$ per MWh) and onshore wind (37–86 \$ per MWh), significantly undercut coal-based generation (71–173 \$ per MWh). While household prices, excluding tax and levies, remain largely stagnant or diminish with renewable electricity growth, household electricity prices including tax and levies show positive correlation (slope = 0.153). These differences can be attributed to the implementation of green taxes and carbon pricing mechanisms. Furthermore, Oyewole and Thopil (Oyewole & Thopil, 2025) investigated industrial electricity markets of 22 countries from the Organisation for Economic Co-operation and Development (OECD), determining that the expansion of renewable electricity

exerts negligible influence on pricing, while taxation represents the most significant factor contributing to the increase in industrial electricity prices.

To evaluate variations in correlation coefficients, the average correlation between electricity prices and the growth of renewable electricity was calculated for seven group of countries. For each individual country, a specific Pearson correlation coefficient was first calculated and further averaged within each group of countries. Groups 1-4 represent countries with a moderate increase in renewable electricity, while groups 5, 6, and 7 include countries with high increase of renewable electricity. Lithuania was excluded from this part of the study because the correlation coefficient could not be calculated for the same period due to insufficient data on household electricity prices. In Figure 6, two average correlation coefficients are presented for each group: one including tax and levies (green) and one excluding tax and levies (orange). The blue bars indicate the average share of electricity produced from renewable sources for the years 2003, 2013, and 2023, while a grey dashed line indicates the zero-correlation threshold.

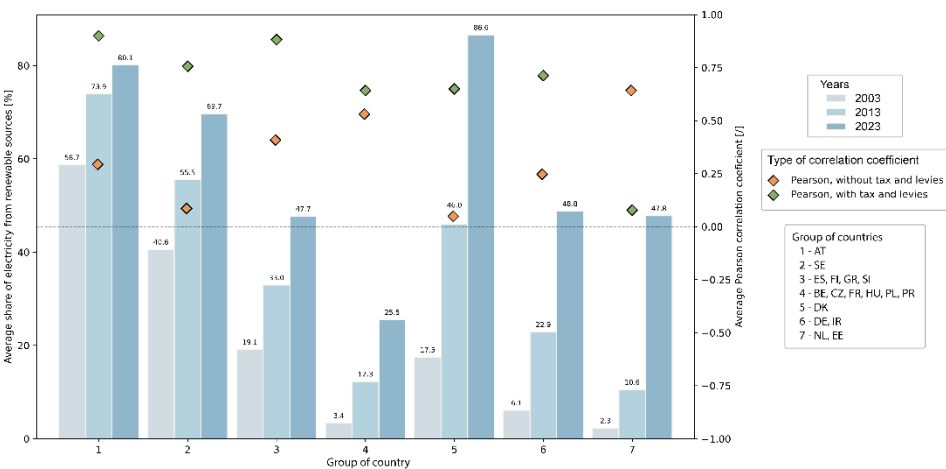


Figure 6: Mean Pearson correlation coefficient (r) for household electricity price and share of electricity produced from renewable sources in the electricity production mix for groups of countries (2003 – 2023).

Source: Electricity prices are based on Eurostat database (Eurostat, 2021; Eurostat, 2025), while share of electricity from renewable sources is based on International Renewable Energy Agency (IRENA) database (IRENA, 2025b).

Figure 6 illustrates that Pearson correlation coefficients do not follow a uniform trend across the studied countries. All the evaluated groups of countries exhibit a positive correlation coefficient. Low correlation is evident for Sweden (2) and Denmark (5) when comparing renewable electricity to prices excluding tax and levies. Most countries exhibit higher correlation when tax and levies are included in the electricity price, except the Netherlands and Estonia (7). Additionally, the smallest discrepancies between the two price types are found in Group 4, while the highest difference is found in Sweden (2).

Based on Figure 6 it cannot be concluded that a simple correlation exists between price and the share of renewable electricity in the national electricity mix. Many other factors such as national fundings, vouchers, social welfare policies, and carbon taxes influence final electricity prices (Rosenow et al., 2023). Consequently, electricity costs are driven by complex fiscal policies and levies rather than being exclusively dictated by generation technology or environmental externalities (George et al., 2024).

5 Conclusion

In this study, electricity generation mixes for selected EU countries were analysed for the period from 2003 to 2023. EU countries have adopted different strategies in their electricity production systems to align with the EU Green Deal commitments and mitigate climate change. Based on these national strategies and increase in production of renewable electricity in national electricity production mixes, countries can be categorised into eight different groups: four with a moderate renewable electricity growth and four with a more accelerated growth (Denmark, Germany, Lithuania and the Netherlands).

The study revealed that increasing the share of renewable energy sources in the national electricity production mix does not guarantee the reduction in environmental burdens, while the environmental impacts are highly related with the selection of electricity production technologies (hydro, wind, solar, geothermal, fossil based, nuclear, etc). Moreover, focusing only on GHG emission reductions through global warming impacts can lead to false conclusions, as the global warming impact category is not necessarily the most influential one. In the case of Slovenia,

it is crucial to reduce other environmental impacts in the energy sector, as these contribute more significantly to total environmental impacts than global warming impacts, which are emphasized by the EU Renewable Energy Directive.

Additionally, the relationship between household electricity prices (excluding and including taxes and levies) and the share of electricity generated from renewable sources was analysed for EU countries, using the Pearson correlation coefficient, resulting in no uniform trend across the studied countries. A higher share of electricity produced from renewable sources does not ensure that such electricity will have lower costs for households, therefore consumers might not benefit from higher shares of electricity produced from renewables.

The transition to renewable energy sources is not solely a matter of increasing their share in the generation mix, but also involves the design of market structures, investments in grid infrastructure, regulatory frameworks, and fiscal policy. It is consequently challenging to make a straightforward comparison between the prices in correlation with the share of renewables in the electricity production mix across all EU member states. Planning one aspect of sustainability is difficult enough, while planning sustainable business operations is an even more demanding task.

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DEVELOPING SOFT COMMUNICATION SKILLS WITH VIRTUAL REALITY AND ARTIFICIAL INTELLIGENCE

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This paper presents a methodological framework for examining how AI-enhanced virtual reality environments can be used to study soft communication skills within a social research framework. Specifically, it focuses on how experiments conducted in VR environments can integrate AI-generated behavioural metrics with conventional social science research methods such as surveys and transcript analysis. The framework is structured around a small-scale social experiment employing a pre-test/post-test design. The design includes two VR-based communication simulations using the VirtualSpeech platform. To examine how different data sources can be integrated within the experimental framework, AI-generated analytical feedback across multiple speech-related performance categories is combined with structured questionnaires capturing user experience and self-assessed competence before and after the intervention, transcript-based analysis of participants' spoken responses, and AI-assisted analytical tools. The proposed experimental design combines three complementary layers of data collection: automated behavioural indicators generated by the VR platform, transcript-based qualitative analysis of communication performance, and participant self-report questionnaires capturing perceived competence and experience. The paper aims to demonstrate how heterogeneous data sources can be systematically integrated into a single experimental framework for studying communication behaviour in immersive environments. It provides methodological insights for researchers designing AI-enhanced VR experiments and supports future interdisciplinary studies of communication.

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1 Introduction

Soft communication skills have become an increasingly important focus in higher education and professional development. Competencies such as public speaking, negotiation, and interpersonal interaction are widely recognised as essential for effective professional performance. At the same time, these competencies remain difficult to observe and evaluate systematically. Traditional approaches to studying communication skills typically rely on self-reported questionnaires, observational assessments, or qualitative reflections on communication behaviour. While these methods provide valuable insights into perceived competence and learning experiences, they often capture communication outcomes only indirectly and provide limited access to detailed behavioural patterns during the communication process itself (Alt et al., 2023).

Recent advances in immersive digital technologies have introduced new possibilities for studying communication behaviour in controlled yet realistic environments. Virtual reality (VR) systems enable participants to engage in simulated professional situations in which they interact with virtual audiences or conversational partners (Chen et al., 2024). Such environments can generate a strong sense of presence and can elicit behavioural responses comparable to those observed in real social interactions. As a result, VR technologies have increasingly been explored as platforms for training (Tangsrapiroj et al., 2024) and analysing (Bozkir et al., 2026) communication skills in education and professional development contexts.

In addition to immersive simulation, contemporary VR platforms often incorporate artificial intelligence (AI) components capable of analysing communication behaviour in real time (Wang et al., 2025) (Lampropoulos, 2025). These systems can generate structured feedback based on behavioural indicators such as speech rate, vocal clarity, eye contact, body posture, and filler word frequency (Zhang et al., 2022). The availability of such automatically generated behavioural metrics creates new opportunities to analyse communication performance beyond traditional observational methods.

However, the increasing use of immersive simulation platforms also introduces methodological challenges for social research. Behavioural data generated by digital platforms differ substantially from the survey instruments, qualitative observations,

and discourse analyses commonly used in social science research. Integrating these heterogeneous data sources, therefore, requires careful experimental design and methodological reflection, particularly when behavioural metrics, subjective self-reports, and qualitative communication data are analysed together.

This paper addresses this methodological challenge by presenting a methodological pilot experimental framework that combines VR-based communication simulations with survey instruments and transcript analysis. It explores how behavioural metrics generated within immersive communication simulations can be systematically integrated with established social research methods.

The central methodological research question is:

RQ: How can experiments conducted in AI-enhanced VR environments be designed so that behavioural metrics generated by the platform can be meaningfully integrated with standard social science research methods, such as surveys and transcript analysis?

The remainder of the paper is structured as follows. Section 2 reviews the theoretical background related to soft communication skills, virtual reality environments, artificial intelligence, and experiential learning. Section 3 presents the experimental design, including the participant sample, VR simulation procedure, and data collection instruments. Section 4 summarises the methodological framework, its feasibility, potential issues, and implications for communication skills research in immersive learning environments.

2 Background

2.1 Soft skills

Soft skills are commonly distinguished from technical competencies, as “hard skills are referring to technical or practical abilities, and soft skills are relating to interpersonal capabilities” (Lamri & Lubart, 2023). These interpersonal capabilities include a wide range of attributes, such as “communication skills, leadership position, decision making skills, responsibility, empathy, self-esteem, critical thinking, analytical thinking, emotional intelligence” (Avdeeva et al., 2024), which are increasingly valued in educational and professional contexts.

Research consistently demonstrates their importance, showing that “those who scored highly on basic skills were more likely to earn higher wages throughout their careers, move into more advanced roles, learn specialized skills more quickly, and were more resilient to industry changes” (Hosseinioun et al., 2025). Despite their significance, assessment remains challenging, as “soft skills are hard to measure and evaluate” (Moldoveanu, 2024).

2.2 Virtual reality

Virtual Reality is a technology that enables users to interact with computer generated environments designed to resemble real world experiences. According to Burdea and Coiffet, VR is defined as “a simulation in which computer graphics is used to create a realistic looking world” that “is not static, but responds to the user’s input (gesture, verbal command, etc.)” (Burdea & Coiffet, 2003). This definition emphasises the interactive and dynamic nature of virtual environments. From an experiential perspective, VR has been described as “a transformative technology that simulates environments through computer-generated imagery, aiming to replicate real-world experiences” (Arcón, 2025). This highlights VR’s capacity to create immersive experiences that support a strong sense of presence. In addition, Virtual Reality is understood as “a collection of technologies that allow people to interact efficiently with 3D computerised databases in real time using their natural senses and skills” (McCloy & Stone, 2001). This definition underscores the multisensory, intuitive interaction that distinguishes VR from traditional computer-based systems. One applied example of VR technology is the VirtualSpeech platform, an “award winning soft skills training platform with VR and AI integration” that focuses on communication competencies such as public speaking, sales, and leadership and has been used by hundreds of thousands of learners to improve performance through realistic practice exercises (Gugenishvili & Chunashvili, 2026).

2.3 Generative AI

“Generative Artificial Intelligence refers to artificial intelligence systems with the capability to create text, images, or other forms of media through the utilisation of generative models.” These models “acquire an understanding of patterns and structures within their training data, subsequently generating novel data with akin characteristics,” and generative AI therefore “encompasses various types, each

tailored for specific tasks or forms of media generation” (Sengar et al., 2025). One of the most prominent applications of generative AI is ChatGPT, which is a chat based Generative Pre-trained Transformer (GPT). ChatGPT is described as one of the most widely used generative AI tools, with applications spanning diverse academic and professional fields, including linguistics, psychology, education, medicine, and management (Madzik et al., 2026).

2.4 The importance of VR and AI in soft skills development

Virtual reality and artificial intelligence are increasingly applied in soft skills development due to their ability to combine experiential learning with data driven evaluation. As stated in recent research, “Soft skills training using artificial intelligence and virtual reality is an innovative approach in the field of interpersonal skills development. Traditional methods, especially for younger generations, do not provide participants with the opportunity to practically apply acquired knowledge in realistic, non-linear scenarios. The use of AI and VR allows for the creation of immersive environments in which participants can safely practice and improve their skills in simulated situations similar to real professional challenges” (Budnarowski et al., 2025).

AI systems can be trained to analyse communication behaviour and deliver instant, structured feedback, while VR enables realistic simulation of professional communication contexts. When combined, these technologies enable the observation and partial quantification of soft skills that are otherwise difficult to assess. For example, platforms such as VirtualSpeech enable users to practice diverse communication scenarios in virtual environments while AI evaluates performance indicators, including listenability, content structure, eye contact tracking, body language tracking, words per minute, and filler word frequency (Gugenishvili & Chunashvili, 2026). This integration enhances both skill practice and the objectivity of soft skills assessment.

2.5 Experiential learning

Experiential learning emphasises learning through direct engagement and active participation rather than passive knowledge acquisition. As defined by Below (2024), “Experiential learning differs from ‘traditional’ modes of knowledge acquisition as

it requires students and teachers to place themselves in potentially unfamiliar places (literally or theoretically) and become active participants in the co-creation of knowledge”. This perspective highlights experience as a central driver of meaning-making, reflection, and skill development.

A foundational theoretical framework for experiential learning was formulated by Kolb (1984), who proposed a four-stage learning cycle: concrete experience, reflective observation, abstract conceptualisation, and active experimentation.

VR and AI based learning environments align closely with experiential learning theory by providing structured yet immersive experiences that simulate real-world situations. Virtual reality enables learners to engage in concrete experiences within realistic, interactive scenarios, while artificial intelligence supports reflection and conceptualisation by delivering immediate, data-driven feedback. Through repeated experimentation in safe, controlled environments, VR and AI systems operationalise Kolb’s learning cycle and extend experiential learning into domains, such as soft communication skills, where traditional classroom methods are limited (Nakamatsu et al., 2025).

2.6 Assessment of learning outcomes

Evaluating the effectiveness of experiential learning requires appropriate methods for measuring learning outcomes. Because soft skills involve behavioural and cognitive components, research commonly applies a combination of assessment approaches. These include self-report questionnaires measuring perceived competence, performance-based tasks such as simulations or presentations, and pre-test/post-test comparisons to assess improvement after training.

Devedzic et al. (2018) emphasise that soft skills can be assessed using multiple performance indicators, including quantitative measures of observable behaviour and qualitative evaluations based on ratings or observations. Such evaluations may be conducted by teachers, experts, peers, or technology-supported systems using defined variables and rating scales.

For example, Romanenko et al. (2023) evaluated soft-skills learning using theoretical tests, situational tasks, and self-assessment surveys administered before and after the course. Such approaches allow researchers to capture both knowledge acquisition and perceived skill development.

In VR and AI-based learning environments, additional behavioural indicators can be automatically collected during simulations. Systems may record performance metrics such as speech characteristics, eye contact, or interaction patterns, providing objective data that complements traditional evaluation methods.

The reviewed literature indicates that soft communication skills are important but difficult to measure, that VR can provide realistic and controlled environments for communication practice, and that AI-based systems can generate behavioural indicators that complement traditional assessment methods. However, existing studies often treat VR-based training, AI-generated feedback, experiential learning, and soft-skills assessment as distinct areas. Less attention has been given to the methodological challenge of integrating platform-generated behavioural metrics, self-report questionnaires, and transcript-based qualitative analysis within a single social research design. The original contribution of this paper is therefore methodological: it proposes an integrated pilot framework for combining automated VR-generated indicators, participant self-reports, and transcript analysis to study soft communication skills.

3 Proposed Methodology

3.1 Research Design

The methodological framework is designed as a pilot experimental investigation to examine the feasibility of integrating behavioural metrics generated by VR-based simulations with established social science research instruments. Perceptual changes will be assessed using self-report questionnaires administered before and after the experimental intervention. Behavioural performance indicators, such as eye contact, speech rate, and body language metrics, will be continuously evaluated through AI-driven analytics embedded within the VirtualSpeech platform during each VR session. At the conclusion of the experiment, participants will complete an additional questionnaire to assess their perceptions of the VR–AI learning experience.

3.2 Sample

The pilot methodological framework is designed to involve a purposive sample of at least six participants with limited experience in virtual reality, who are exposed to demanding communication situations such as public speaking, job interviews, and professional negotiations. Participants will be divided into two experimental groups, each comprising at least 3 participants, to ensure comparable conditions during the VR simulations. The planned gender composition of the sample will be approximately balanced, aiming to maintain a similar gender distribution across both groups. To strengthen the empirical robustness of the design, the pilot framework can be replicated with additional groups, enabling broader comparison across participant profiles and communication scenarios.

Regarding educational and employment status, the sample is intentionally balanced between students and working professionals. Approximately half of the participants will be university students engaged in part-time work, while the other half will be fully employed individuals. This composition is expected to enable the examination of VR-based communication training across individuals with different levels of professional experience and exposure to formal communication environments.

All participants will be selected based on prior experience with public speaking situations, including academic presentations, job interviews, or formal negotiations. As a result, the experimental tasks will not represent an entirely unfamiliar communicative activity. This criterion is intended to reduce the likelihood that observed outcomes are driven primarily by novice anxiety or lack of familiarity with the task, rather than by the effects of the VR-based training itself.

Participants will also be required to demonstrate general familiarity with virtual reality technology, ensuring that their interaction with the VR environment is not a completely new technological experience. In addition, all participants must confirm that they do not have visual impairments, balance disorders, or other health conditions that could interfere with the safe use of VR equipment.

Because the VR simulations are designed to replicate international professional communication scenarios, all participants will be required to demonstrate fluent English proficiency. This requirement is intended to minimise potential language-

related confounds and ensure that participants can engage naturally and effectively with the simulated communication tasks.

3.3 Experiment Procedure

The experiment is designed to be conducted in a controlled environment and structured into four sequential phases.

In the introductory phase, participants will be asked to sign a consent form agreeing to the anonymous analysis of the collected data for this experiment. They will be briefed on the objectives, structure, and procedures of the experiment. Standardised instructions for using the VR equipment and the VirtualSpeech platform will be provided. Participants will then complete a pretest self-assessment questionnaire measuring baseline levels of self-confidence and anxiety related to public speaking.

The first experimental phase will consist of an initial VR simulation. Group A will receive materials for Case Study 1 (a job interview scenario), while Group B will receive materials for Case Study 2 (a salary negotiation scenario). A deliberate time delay will be implemented to prevent potential information exchange between participants. Each group will be given 15 minutes to prepare an individual five-minute pitch. Presentations will be delivered individually within a standardised virtual environment. Following each presentation, the platform will automatically generate AI-based feedback evaluating key performance indicators, including eye contact, speech rate, filler word usage, speech clarity, body language, and overall performance. After completing the presentations, participants will engage in a brief informal group reflection focusing on perceived challenges and subjective experiences.

The second experimental phase will involve a mirrored exchange of scenarios. Group A will complete Case Study 2, while Group B will complete Case Study 1, again with a time delay between groups. Preparation time, presentation order, simulation conditions, and AI-generated feedback procedures will remain identical to those in the first phase to ensure methodological consistency. This phase will conclude with a short reflective discussion in which participants will compare their first and second performances and discuss perceived improvements.

In the final phase, participants will complete a post-test self-assessment questionnaire measuring potential changes in public speaking self-confidence and anxiety. Additionally, they will complete a structured user-experience questionnaire evaluating the VR tool on perceived usefulness, level of immersion, learning effectiveness, perceived improvement in communication skills, motivation, and engagement.

Upon completion of the final questionnaires, the experimental procedure will be formally concluded, and the collected data will be prepared for analysis to address the paper's research questions.

Table 1: Experiment phases overview.

Phase	Overview	Data Collected (General)
Phase 1: Introductory	Consent, instructions, and baseline assessment	Baseline self-confidence and public speaking anxiety (pre-test questionnaire)
Phase 2: First Experimental Phase	Initial VR simulation (Group A: Interview, Group B: Negotiation)	AI-generated performance metrics (e.g., eye contact, speech rate, clarity, body language); subjective reflections (experience, challenges)
Phase 3: Second Experimental Phase	Scenario exchange with identical procedure	AI-generated performance metrics (same as Phase 2); comparative reflections (perceived improvement, performance differences)
Phase 4: Final Phase	Post-assessment and user experience evaluation	Post-test self-confidence and anxiety; user experience data (usefulness, immersion, learning effectiveness, engagement, perceived improvement)

3.4 Data Collection Instruments:

- **Automated VR performance metrics:** Objective performance data will be collected automatically by the VirtualSpeech platform during each VR simulation. The system will generate standardized AI based feedback immediately after each presentation, capturing both verbal and nonverbal communication indicators. These AI-generated indicators are treated as operational proxies for selected dimensions of communication competence, rather than as direct or complete measures of soft skills.

For example, speech rate and filler word frequency are interpreted in relation to verbal fluency and rhetorical delivery; vocal clarity is linked to intelligibility and message delivery; eye contact and body language are linked to nonverbal communication, interpersonal engagement, and audience orientation; and content structure is linked to coherence, organisation, and persuasiveness. These indicators are therefore analysed as partial behavioural signals that must be interpreted together with transcript-based analysis and self-report questionnaires.

- **Speech transcripts:** All VR presentations will be transcribed verbatim and will serve as the primary qualitative data source. The transcripts will enable detailed examination of discourse structure, communicative coherence, and the expression of soft communication skills across different scenarios.
- **GPT-supported transcript analysis: To support a systematic examination of communication performance, transcripts will be analysed using a custom GPT-based** analytical tool (“Transcript Insight Engine”), designed to assist in identifying patterns related to communication clarity, structure, and soft-skill indicators. The “Transcript Insight Engine” is based on a large language model (GPT-5.3) and is configured with structured prompts to evaluate communication performance across predefined soft-skill categories such as clarity, coherence, confidence, and persuasiveness.

The coding logic is based on identifying transcript evidence for predefined analytical categories, including clarity of expression, coherence of argumentation, confidence in language use, persuasiveness, and audience orientation. The GPT-supported tool is used to assist the systematic identification and comparison of these patterns, rather than to replace researcher interpretation.

The analysis combines qualitative interpretation with simple scoring based on patterns in language and communication behaviour observed in the transcript.

- **Self-report surveys:** Two types of self-report instruments will be administered via the 1KA online survey platform:
 - **a pre-test and post-test self-assessment questionnaire** measuring public speaking confidence and anxiety (PRCS - based items and semantic differential scales),

- **a post-experiment user experience questionnaire** assessing perceived usefulness, immersion, learning effectiveness, motivation, engagement, and perceived skill improvement using a seven-point Likert scale.

3.5 Data Analysis

The data analysis combines descriptive, comparative, and interpretative approaches to examine potential changes in communication performance and participant perceptions throughout the experiment.

Descriptive statistics will summarise automated VR performance metrics and questionnaire responses, including means and difference scores.

Comparative analyses will examine changes between the two simulation rounds through within-participant comparisons (first vs second simulation) and between-group comparisons to assess potential effects of scenario order.

Transcript data will be analysed using a combined qualitative–quantitative approach, integrating discourse analysis with ordinal coding of selected soft skill dimensions. The analysis will focus on identifying patterns of change, variability across participants, and consistency between objective VR performance metrics and participants’ self-reports.

4 Discussion and Summary

The objective of this paper was to propose a methodological framework for examining whether behavioural metrics generated in virtual reality communication simulations can be integrated with established social science research methods. The framework, therefore, focuses on methodological feasibility and ethical considerations.

The proposed framework indicates how such an integrated methodological approach can be operationalised. The VR platform can generate structured behavioural indicators related to communication performance, such as speech rate, filler word frequency, eye contact, and body posture. For example, filler word

frequency may relate to constructs such as verbal fluency and cognitive load, while speech rate may reflect aspects of vocalics and rhetorical delivery. Eye contact indicators may be interpreted in relation to interpersonal engagement and audience connection. These indicators could be combined with transcript-based discourse analysis and participant self-report questionnaires. The use of these three complementary data sources can enable observation of communication behaviour from multiple perspectives and provide insight into how immersive technologies may expand the methodological tools available for studying soft communication skills.

A limitation identified concerns the short duration of the experimental intervention. The proposed experiment consists of two simulation rounds conducted within a single session, which may not be sufficient for measurable behavioural change in complex communication skills. Nevertheless, the framework demonstrates how VR environments can function as controlled experimental settings in which communication behaviour can be systematically recorded and analysed. The framework primarily represents a proof of concept for the proposed methodological approach rather than generalizable evidence of communication skill improvement across broader populations.

From a methodological perspective, the experiment provides a preliminary answer to the research question. VR-based experiments can integrate behavioural metrics with conventional social research methods by combining three complementary layers of data collection: automated behavioural indicators generated by the VR platform, transcript-based qualitative analysis of communication performance, and participant self-report questionnaires capturing perceived competence and experience.

The use of immersive technologies for behavioural measurement also raises ethical considerations. VR systems equipped with AI-based analytics can collect detailed behavioural data such as speech patterns, gaze behaviour, and body movement. Such information may represent sensitive behavioural or biometric data and therefore requires careful ethical management (Bozkir et al., 2026). Transparent informed consent procedures, anonymisation of collected data, and clear communication about the purpose of behavioural measurement are therefore essential components of responsible research design.

The paper establishes the methodological logic for combining automated behavioural metrics with traditional research instruments such as surveys and discourse analysis.

Several open questions remain for future research. First, longer-term studies are required to determine whether repeated VR simulations lead to observable behavioural improvements in communication performance. Second, further methodological work is needed to clarify how platform-generated behavioural metrics relate to established constructs of communication competence. Finally, the ethical implications of collecting detailed behavioural data in immersive learning environments require continued attention as VR and AI technologies become increasingly widespread in educational and research contexts.

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AUDIENCE ENGAGEMENT WITH ELECTRIC, HYBRID AND INTERNAL COMBUSTION VEHICLE CONTENT AMONG AUTOMOTIVE CREATORS

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The transition from internal combustion engine (ICE) vehicles toward hybrid and fully electric vehicles (EVs) is reshaping both the automotive industry and audience interest in mobility technologies within digital media environments. This study investigates whether audience engagement differs between online review videos focused on electric, hybrid, and internal combustion vehicles. The analysis is based on 75 videos published by five established European automotive content creators, with engagement compared using quantifiable platform metrics such as views, likes, comments, video duration, publication date, and channel subscriber counts. The study combines descriptive analysis with non-parametric statistical testing, including Kruskal-Wallis tests, Spearman correlation analysis, and the Mann-Whitney U test. The descriptive results indicate that EV videos achieved the highest average normalized view performance and comment intensity; however, statistically significant differences between powertrain categories were not confirmed. The findings further suggest that video length and the distinction between reach and engagement intensity represent important factors in evaluating automotive content performance. The study contributes to a better understanding of digital audience engagement in automotive review content and provides exploratory implications for automotive brands and content creators seeking to optimize communication strategies across different powertrain categories.

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1 Introduction

1.1 Industrial Transformation and Strategic Tensions in the Transition to Electromobility

The transition toward electromobility is frequently presented as a necessary and technologically inevitable pathway toward decarbonisation. However, existing research suggests that this transition is embedded in structural, economic, and political tensions that may limit its transformative potential. At the European level, industrial policy has been strongly oriented toward supporting green transformation within the automotive sector. Nevertheless, critical perspectives argue that such policies may primarily reinforce existing industrial structures rather than fundamentally transforming them. Pichler, Krenmayr, Schneider et al. (2021) contend that EU automotive industrial policies predominantly defend economic growth and competitiveness, focus narrowly on innovation policy, and promote ecological modernisation through efficiency improvements rather than absolute emission reductions. As a result, the transformation may at best modernise the existing system and at worst conserve structurally unsustainable pathways. A related strategic dilemma concerns the organisation of production. Girke et al. (2025) emphasise the importance of maintaining core technological capabilities in-house, particularly in the context of EV development. Their findings highlight design capabilities and customer centricity as key drivers of competitiveness and introduce the concept of a “Technology Multiplier” to capture the long-term strategic value of internal production in terms of innovation and adaptability. This perspective suggests that the transition is not merely technological but deeply strategic, involving decisions about capability retention and industrial sovereignty. At the same time, the material and institutional embeddedness of the automotive sector constrains rapid transformation. Pichler, Krenmayr, Maneka et al. (2021) identify interconnected material features and competing imaginaries of improvement, diversification, and transformation within the Austrian automotive industry. Although incremental change is widely perceived among the workforce, strong confidence in existing expertise may also support more systemic transformation. The industry thus embodies both strategic dilemmas and latent transformative capacities. The economic and ecological implications of battery electric vehicles (BEVs) further complicate the transition narrative. Morgan (2020) argues that although BEVs may represent a superior alternative to internal combustion engines, a substitution-based

transition that maintains current scales of private transportation could contribute to exceeding the remaining carbon budget under the Paris Agreement. In such a scenario, electrification may become a “successful failure,” delivering technological change without achieving systemic sustainability goals. These structural constraints are particularly visible in smaller, export-oriented economies. Gažo et al. (2022) demonstrate that the transformation of the Czech and Slovak automotive industries is constrained by path dependency in public institutions and foreign ownership of automotive firms. This ownership structure limits the ability of local actors to steer transformation proactively, reinforcing a reactive rather than strategic position within global value chains. Taken together, the literature indicates that the transition to EVs is shaped not only by technological progress but also by industrial policy priorities, ownership structures, material constraints, and strategic production decisions. The effectiveness of the transition therefore depends on whether it remains a form of incremental ecological modernisation or evolves into a more systemic restructuring of mobility systems.

1.2 Barriers to EV Adoption: Economic, Technological and Psychological Dimensions

Beyond industrial supply-side considerations, the success of the EV transition depends significantly on consumer adoption. Empirical evidence identifies multiple barriers that may slow or distort the diffusion of EVs. Infrastructure availability and total cost of ownership are consistently identified as primary obstacles. Kumar et al. (2025) highlight charging infrastructure, driving range, battery life, safety, performance, and reliability as decisive factors influencing consumer decisions. Without addressing these practical concerns, the transition risks stagnation or backlash. Similarly, Alanazi (2023) notes that proposed solutions—such as expanding charging networks, battery swapping, and technological improvements – are technically complex and financially demanding. Consumer uncertainty further shapes adoption dynamics. Bakhuis et al. (2025) find that while financial incentives constitute the strongest driver of EV uptake, perceived loss of flexibility and battery degradation remain dominant barriers. These findings suggest that economic incentives alone may be insufficient unless accompanied by trust-building measures.

Demographic and contextual factors also influence adoption. Champahom et al. (2024) show that younger adults and individuals with strong environmental values are more likely to adopt EVs, whereas rural residency and ownership of conventional vehicles reduce adoption likelihood. These results indicate that EV adoption is not homogeneous but segmented along socio-demographic and attitudinal lines. Policy recommendations frequently emphasise targeted education, communication, and differentiated incentive schemes. Bakhuis et al. (2025) and Anwar et al. (2025) advocate context-sensitive information strategies combined with accessible infrastructure and supportive regulation. Collectively, these studies imply that adoption barriers are multi-dimensional and require integrated economic, infrastructural, and communicative responses.

1.3 Communication, Perception and the Role of Digital Media

In addition to structural and economic determinants, communication plays a central role in shaping public attitudes toward EVs. The digital era has significantly reconfigured the automotive landscape, compelling industry actors to respond to rapidly evolving information ecosystems (Pérez-Moure et al., 2025). A recurring finding in the literature concerns insufficient consumer knowledge and ecological awareness. Abbasi et al. (2025) demonstrate a strong relationship between advertisement exposure, EV knowledge, and purchase intention, suggesting that communication can partially mitigate informational deficits. Lashari et al. (2021) further identify environmental and economic perceptions as the strongest predictors of EV purchase intention, while technological concerns exert a negative effect. These results indicate that the framing of EVs around environmental and cost benefits may be more effective than emphasising technological sophistication alone. Social influence and normative pressure also shape attitudes. Lashari et al. (2021) show that social influence positively affects environmental concern and brand preference. Similarly, Wang et al. (2025) find that societal concern predicts interest in innovation. These findings suggest that EV adoption is embedded in broader social narratives and identity dynamics. Digital marketing and segmentation strategies appear particularly relevant in this context. Oliver and Rosen (2010) emphasise the importance of tailoring policy and marketing techniques to distinct consumer segments, considering factors such as skepticism, technological savviness, and price sensitivity. More recent research by Henderi (2025) confirms that segmented digital marketing campaigns—emphasising luxury and innovation for

premium segments and practicality and cost-effectiveness for mainstream clusters—can enhance strategic effectiveness. Nugroho and Harjanto (2023) further stress the need to combine selling with education in marketing communication activities. Social media platforms constitute an especially influential arena for shaping green purchase intention. Charan et al. (2024) identify social media engagement as a mediating factor between brand experience and green purchase intention, while Sun and Wang (2019) find that social media marketing positively affects subjective norms and product knowledge. However, sentiment analysis suggests that online discourse may not be uniformly positive. Li and Ullah (2025) observe increasing contestation in infrastructure discussions, with sentiment converging toward negativity despite growing volume. User-generated content and reviews provide additional insight into public perceptions. Wyskowski (2024a, 2024b) identifies increasing engagement with EV-related YouTube content and a diverse range of topics discussed in comments, including technical aspects and infrastructure concerns. Yıldız et al. (2025) report that negative comments may outnumber positive ones in certain contexts, indicating persistent skepticism. At the same time, large-scale review analyses demonstrate that vehicle range and long-term performance significantly affect satisfaction (Shi et al., 2025). Despite the growing body of research on digital communication and EV adoption, limited attention has been devoted to the systematic analysis of performance metrics such as likes, shares, and comments in relation to different powertrain categories. While consumer sentiment and communication strategies are widely discussed, the interaction between content characteristics and engagement indicators remains underexplored.

The reviewed literature demonstrates that the transition to electromobility is shaped by interconnected industrial, economic, and communicative dynamics. Structural constraints, strategic production decisions, consumer uncertainty, and digital discourse collectively influence the trajectory of EV adoption. However, although prior research provides substantial insight into policy dilemmas, consumer barriers, and communication strategies, comparatively little attention has been paid to how EV-related content performs within digital platforms in comparison to alternative powertrain categories. In particular, engagement indicators such as views, likes, comments, and video characteristics have not been systematically analysed as proxies for audience interest and discussion intensity.

Addressing this gap contributes to a more nuanced understanding of how digital attention dynamics interact with broader industrial and societal transformation processes.

2 Methodology

The study builds on a structured literature review focused on three thematic areas: (1) transformation of automotive mobility and the digital media environment, (2) audience engagement and automotive content consumption, and (3) the role of social media and content creators in shaping consumer interest. The literature review primarily utilized publications indexed in Web of Science and Scopus within business, marketing, and media categories. Existing research extensively covers automotive consumer behavior, regulatory pressures supporting transition towards electric mobility and communication strategies related to EV adoption. However, limited attention is devoted to automotive content creators and their potential to influence audience interest in hybrid and electric vehicles. This gap motivated the empirical research presented in this study.

Empirical data were collected during January and February 2026 on the YouTube platform, which represents one of the dominant environments for automotive video reviews. The empirical sample was constructed using purposive sampling. The selection of creators was based on a preliminary review of automotive reviewers on YouTube and on online articles identifying relevant automotive content creators. The aim was to include established creators who regularly publish vehicle review content and for whom comparable videos focused on electric, hybrid, and internal combustion engine vehicles were publicly available.

The selected creators represented a geographically diverse sample of European automotive review channels, including creators operating in English-, German-, Dutch-, and Spanish-language online environments. Their audience size varied substantially, ranging from approximately 171,000 to 10.8 million subscribers, which enabled the study to include both large international channels and smaller, more specialized automotive creators. This diversity was intentionally included to capture engagement patterns across channels with different audience reach and market positioning. The intention was therefore not to construct a statistically representative

sample of all automotive creators, but to create a diverse exploratory sample suitable for comparing engagement patterns across powertrain categories.

For each creator, fifteen review videos were analyzed, consisting of:

- five electric vehicle (EV) reviews,
- five hybrid vehicle reviews,
- five internal combustion engine (ICE) vehicle reviews.

The final dataset consisted of 75 videos, with 25 videos representing each powertrain category. This sample size provides an initial empirical basis for identifying descriptive tendencies and relationships between selected engagement indicators, such as views, likes, and comments. However, the sample remains limited, and the findings should be interpreted as exploratory. A larger dataset including more creators, more videos, additional countries, and a longer observation period would be necessary to test the robustness and generalizability of the results in future research.

For each video, the following variables were collected:

- publishing account,
- video title,
- reviewed car brand,
- identification of vehicle powertrain type, based on information presented in the video title, description, or video content,
- number of views,
- video duration,
- number of channel subscribers,
- number of likes,
- number of comments,
- publication date,
- presence of chapter segmentation,
- recognizability of the powertrain type before clicking on the video,
- direct video link.

Data were recorded in Microsoft Excel, followed by data cleaning procedures to ensure dataset consistency. Selected variables, including vehicle category, powertrain identification, views, video duration, subscriber count, likes, comments, chapter segmentation, and recognizability of the powertrain type before clicking, were subsequently visualized to compare engagement patterns across vehicle categories.

Views were used to indicate audience reach and attention, likes were used to indicate basic positive audience feedback, and comments were used to indicate discussion intensity. These metrics represent different forms of audience engagement and were therefore interpreted separately. A higher number of comments was not automatically understood as positive engagement, as comments may also reflect controversy, criticism, or debate. To improve comparability across channels and videos with different audience sizes, several metrics were normalized. Views were normalized per 1,000 subscribers, likes were normalized per 1,000 views, and comments were normalized per 10,000 views. In addition, combined engagement was calculated as the sum of likes and comments normalized per 1,000 views.

Metrics were processed and compared across different powertrains. The following associations were visualized, tested, and commented:

- normalized views per 1,000 subscribers by powertrain category,
- release timeline of the examined videos by powertrain category to examine creators' vehicle category preferences,
- likes per 1,000 views by powertrain category,
- comments per 10,000 views by powertrain category,
- combined engagement per 1,000 views by powertrain category,
- association between video length and views per 1,000 subscribers,
- association between video length and combined engagement per 1,000 views,
- association between normalized views and combined engagement per 1,000 views,
- association between recognizability of the powertrain type before clicking on the video and views per 1,000 subscribers.

Since engagement metrics on digital platforms are often unevenly distributed and the sample size was limited, non-parametric statistical tests were used. The Kruskal-Wallis test was applied to examine whether engagement indicators differed between ICE, EV, and hybrid videos. Spearman correlation analysis was used to examine associations between video length and engagement indicators, as well as the relationship between normalized views and combined engagement. The Mann-Whitney U test was used to examine whether the recognizability of the powertrain type before clicking on the video was associated with normalized view performance.

The analysis enables the identification of preliminary associations between audience engagement and content characteristics, such as vehicle category, video length, and pre-click recognizability of the powertrain type. However, the results should be interpreted as exploratory associations rather than causal effects. Several limitations were considered already in the empirical design. The study did not control for thumbnail design, title structure, creator-specific audience characteristics, brand popularity, model novelty, publication timing, or the broader media context in which individual videos were released. Furthermore, the analysis did not include sentiment analysis of comments. Therefore, a higher number of comments should not automatically be interpreted as positive engagement, as comments may also reflect controversy, criticism, or debate.

The findings provide practical implications for both automotive brands and independent content creators by supporting decision-making related to the production of automotive content optimized for social media engagement, while also offering an exploratory basis for more robust future research.

3 Results

To improve the clarity of presentation, the results were divided into two subsections. Subsection 3.1 presents descriptive statistics, while Subsection 3.2 reports the results of statistical tests examining associations between selected variables.

3.1 Descriptive statistics

Figure 1 illustrates one of the key YouTube metrics, namely view count, which was normalized as views per 1,000 subscribers due to substantial differences in subscriber counts across the examined channels.

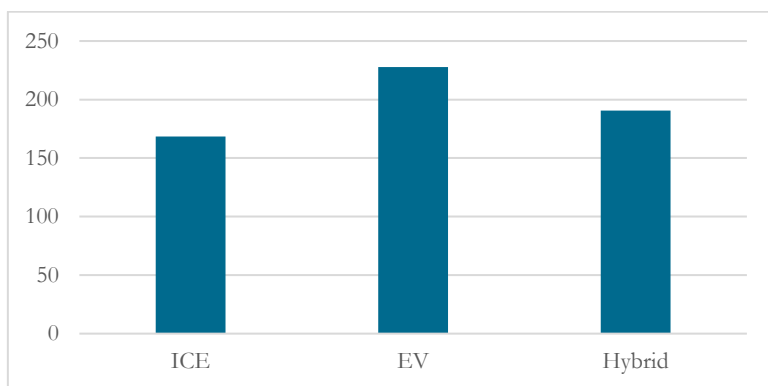


Figure 1: Normalized views per 1,000 subscribers by powertrain category

Source: own processing.

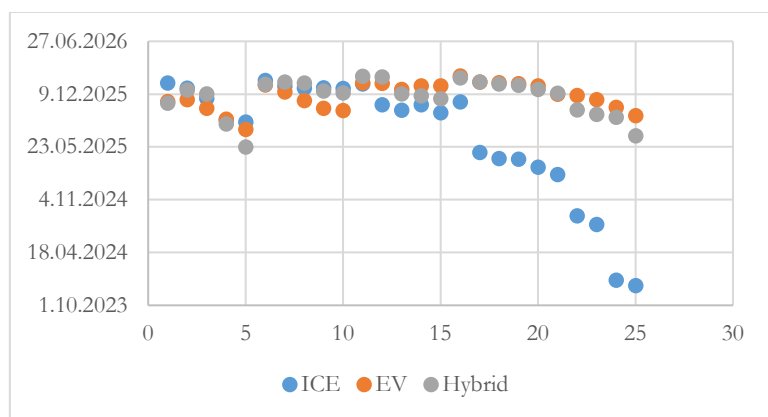


Figure 2: Release timeline of the examined videos by powertrain category

Source: own processing.

As shown in Figure 1, EV videos generated an average of 228 views per 1,000 subscribers, which represents approximately 20% more than hybrid vehicles and 35% more than ICE vehicles, the latter generating the lowest number of views

among the three categories. The number of views provides an important signal of audience reach and potential interest in specific vehicle types.

Figure 2 presents the timeline of the release dates of the examined videos.

None of the examined EV and hybrid videos were released before May 2025, and a similar publication frequency can be observed between these two categories. However, ICE vehicles exhibit a lower upload frequency overall. As illustrated in Figure 2, some of the five most recent ICE review videos on the examined channels were released as early as 2024. This may reflect the ongoing transition toward an EV/Hybrid-dominated market environment, which also relates to the findings presented in Figure 1. The observed release pattern may correspond with increased attention to EV and hybrid vehicles, although it may also reflect market availability, creator strategy, or model release timing.

Figure 3 compares the number of likes per 1,000 views across the three examined powertrain categories.

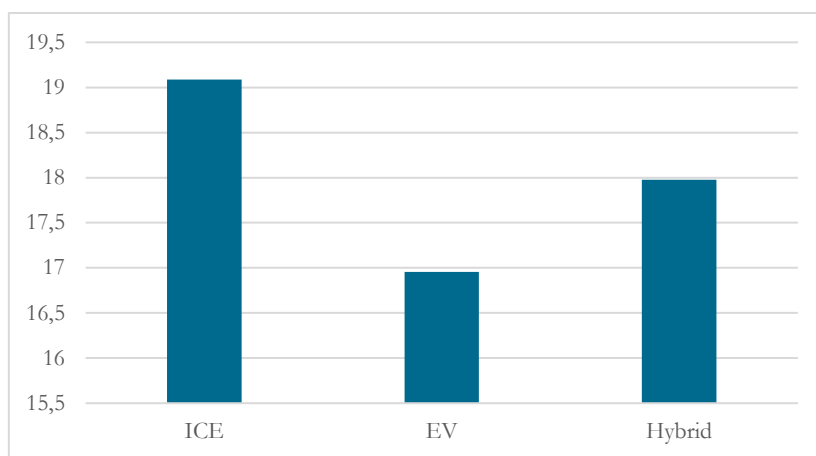


Figure 3: Likes per 1,000 views by powertrain category

Source: own processing.

To ensure comparability, the number of likes was normalized per 1,000 views in Figure 3. Although ICE vehicles received the lowest overall view counts and are currently less frequently reviewed, they performed best in this metric, achieving 19

likes per 1,000 views. Hybrids reached 18 likes per 1,000 views, while EV videos achieved 17 likes per 1,000 views. Given the relatively small differences between the categories, no conclusions can be drawn regarding relative popularity based solely on this metric.

Figure 4 compares the number of comments per 10,000 views across the three examined powertrain categories.

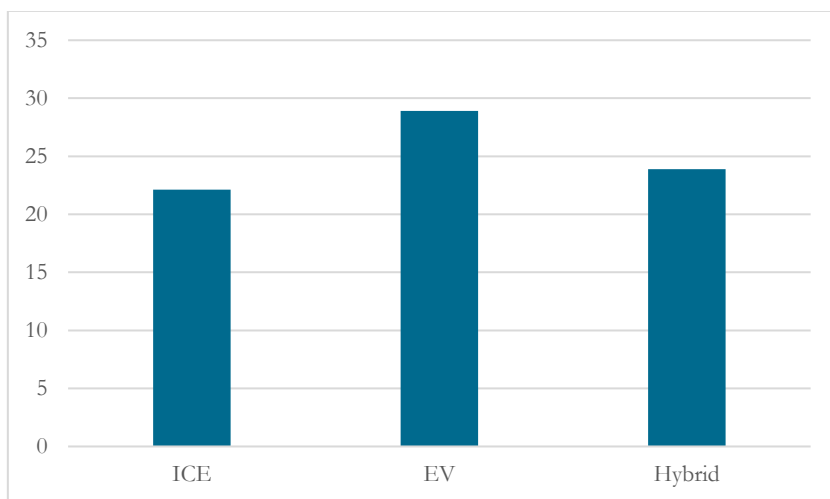


Figure 4: Comments per 10,000 views by powertrain category

Source: own processing.

Due to the lower absolute number of comments, the data were normalized per 10,000 views in Figure 4. In contrast to Figure 3, the ranking differs, with ICE vehicles placing last at 22 comments per 10,000 views, hybrids at 24 comments per 10,000 views, and EVs at 29 comments per 10,000 views. While the difference between ICE and hybrid vehicles is minimal, EV videos generated approximately 31% more comments per 10,000 views compared to ICE vehicles, suggesting that EV-related content may stimulate more audience discussion. However, this should not automatically be interpreted as positive engagement, as comments may also reflect criticism, controversy, or debate.

Figure 5 examines another important variable that may influence view performance: video length.

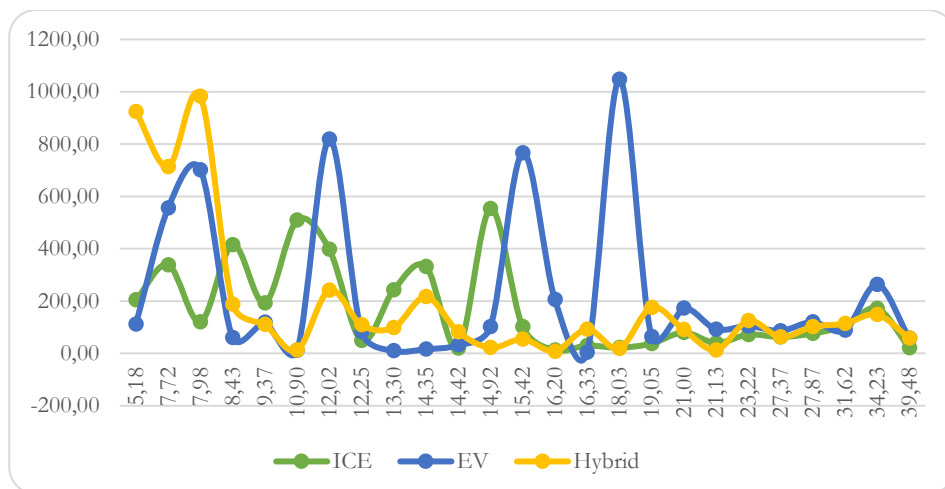


Figure 5: Relationship between video length and views per 1,000 subscribers

Source: own processing.

Figure 5 illustrates the relationship between video length (X-axis) and normalized views per 1,000 subscribers (Y-axis). The results suggest that viewers generally prefer shorter videos, regardless of powertrain type. Based on the data, videos longer than 15 minutes do not appear to generate higher performance in the ICE and hybrid categories. However, EV reviews demonstrate relatively strong performance even within the 15 to 20 minute range. Overall, shorter videos appear to represent the prevailing trend across categories. Therefore, creators should prioritize concise, information-rich content rather than artificially extending video duration to include excessive detail.

3.2 Statistical testing

3.2.1 Differences between powertrain categories

The Kruskal-Wallis test was used to examine whether ICE, EV and hybrid videos differed significantly in the selected engagement indicators in Table 1.

The Kruskal-Wallis tests did not identify statistically significant differences between ICE, EV and hybrid videos in views, likes, comments or combined engagement. Although EV videos achieved the highest average view performance and comment

intensity, these differences were not statistically confirmed in the examined sample. Therefore, the results should be interpreted as descriptive tendencies rather than evidence of clear performance differences between powertrain categories.

3.2.2 Association between video length and engagement indicators

Table 1: Kruskal-Wallis test of engagement metrics by powertrain category

Metric	Test	H-statistic	p-value	Interpretation
Views per 1,000 subscribers	Kruskal-Wallis	0.029	0.985	Not statistically significant
Likes per 1,000 views	Kruskal-Wallis	0.035	0.983	Not statistically significant
Comments per 10,000 views	Kruskal-Wallis	1.659	0.436	Not statistically significant
Combined engagement per 1,000 views	Kruskal-Wallis	0.001	0.999	Not statistically significant

Source: own processing.

Spearman correlation analysis was used to examine whether video length was associated with views and engagement intensity in Table 2.

Table 2: Spearman correlation analysis of video length, views, and engagement

Relationship	Spearman rho	p-value	Interpretation
Video length x views per 1,000 subscribers	-0.303	0.008	Weak negative, statistically significant
Video length x likes per 1,000 views	0.294	0.010	Weak positive, statistically significant
Video length x comments per 10,000 views	0.472	<0.001	Moderate positive, statistically significant
Video length x combined engagement per 1,000 views	0.327	0.004	Weak positive, statistically significant

Source: own processing.

The results indicate that longer videos were associated with lower normalized view performance, but with higher engagement intensity among those who watched them. This suggests that shorter videos may be more effective for maximizing reach, while longer videos may attract a narrower but more involved audience that is more likely to like or comment on the content.

3.2.3 Relationship between reach and combined engagement

A further Spearman correlation was calculated to examine whether higher normalized view performance was associated with higher combined engagement per view in Table 3.

Table 3: Spearman correlation analysis of reach and combined engagement

Relationship	Spearman rho	p-value	Interpretation
Views per 1,000 subscribers x combined engagement per 1,000 views	-0.839	<0.001	Strong negative, statistically significant

Source: own processing.

The strong negative relationship indicates that higher reach did not translate into higher engagement intensity. Videos with broader reach may attract more passive viewers, while videos with lower reach may appeal to a more specific and responsive audience. This finding supports the need to distinguish between reach-oriented metrics and engagement-oriented metrics when evaluating automotive content performance.

3.2.4 Recognizability of powertrain type before clicking

The Mann-Whitney U test was used to examine whether videos in which the powertrain type was recognizable before clicking achieved different normalized view performance compared with videos in which the powertrain type was not clearly recognizable before clicking in Table 4.

Table 4: Mann-Whitney U test of powertrain recognizability before clicking

Metric	Recognition before clicking	n	Mean	Median	U-statistic	p-value	Interpretation
Views per 1,000 subscribers	Yes	46	224.68	107.20	705.0	0.683	Not statistically significant
Views per 1,000 subscribers	No	29	149.31	92.59	-	-	-

Source: own processing.

Although videos with recognizable powertrain type before clicking achieved a higher average number of views per 1,000 subscribers, the difference was not statistically significant. Therefore, the recognizability of the powertrain type alone cannot be considered a statistically confirmed driver of view performance in the examined sample. From a practical perspective, this suggests that explicitly communicating the powertrain type may be useful, but it is unlikely to be sufficient on its own; title attractiveness, thumbnail design, brand relevance and model novelty may play an equally or more important role.

4 Discussion

The empirical findings provide several insights into audience engagement with automotive review videos focused on ICE, EV and hybrid vehicles. Descriptive results suggest that EV-related videos achieved the highest average normalized view performance and the highest comment intensity. This indicates that EV content may currently attract higher digital attention and stimulate more audience discussion than hybrid and ICE content. This pattern is consistent with prior research emphasizing the increasing societal relevance of electromobility and the role of digital media in shaping consumer perceptions of mobility transition (Pérez-Moure et al., 2025). It also corresponds with findings showing that online discussions about EVs often involve infrastructure, performance, range and reliability concerns (Li & Ullah, 2025; Wyskowski, 2024a, 2024b).

However, the statistical results require a more cautious interpretation of these descriptive differences. The Kruskal-Wallis tests did not confirm statistically significant differences between ICE, EV and hybrid videos in views, likes, comments or combined engagement. Therefore, the higher average performance of EV videos should be interpreted as a descriptive tendency rather than evidence of a statistically confirmed advantage of EV-related content. This finding is important because it suggests that powertrain category alone may not be sufficient to explain engagement performance. Other factors, such as the reviewed brand, model novelty, publication timing, title structure, thumbnail design or creator-specific audience characteristics, may also influence how automotive videos perform.

The results also show that different engagement indicators should not be interpreted in the same way. While EV videos achieved the highest average views and comments, ICE videos performed slightly better in likes per 1,000 views. This suggests that views, likes and comments may reflect different audience reactions. Views indicate reach and attention, likes indicate basic positive feedback, and comments indicate discussion intensity. A higher number of comments should not automatically be understood as positive engagement, as EV-related content may also generate debate, criticism or controversy. This interpretation is consistent with research showing that online discourse about EVs can include both supportive and skeptical reactions (Li & Ullah, 2025; Yıldız et al., 2025).

One of the most relevant findings concerns video length. Spearman correlation analysis showed that longer videos were associated with lower normalized view performance, but with higher engagement intensity. This suggests that shorter videos may be more effective for maximizing reach, while longer videos may engage a narrower but more involved audience. From the perspective of content creators, this means that video length should be adapted to the communication goal. If the aim is to maximize views and reach, concise and information-rich videos may be more effective. However, if the aim is to encourage discussion, explanation and deeper audience involvement, longer videos may still be valuable, especially in technically complex topics such as EVs.

The strong negative relationship between normalized views and combined engagement further supports the need to distinguish between reach and engagement intensity. Higher view performance did not automatically translate into higher engagement per view. Videos with broader reach may attract more passive viewers, while videos with lower reach may appeal to a more specific and responsive audience. This finding is particularly relevant for automotive brands and content creators, as it suggests that the success of online automotive content should not be evaluated only through view counts. Depending on the campaign objective, engagement intensity, likes, comments and audience discussion may be equally important indicators.

The recognizability of the powertrain type before clicking on the video also provides an interesting practical insight. Videos in which the powertrain type was recognizable before clicking achieved a higher average number of views per 1,000 subscribers

than videos in which it was not clearly recognizable. However, the Mann-Whitney U test did not confirm this difference as statistically significant. This suggests that explicitly communicating whether the reviewed vehicle is electric, hybrid or ICE may be useful from a content positioning perspective, but it cannot be considered a statistically confirmed driver of view performance in the examined sample. The attractiveness of the title, thumbnail design, brand relevance and novelty of the reviewed model may play an equally or more important role.

Overall, the findings suggest that audience engagement with automotive content is shaped by a combination of vehicle category, video characteristics and communication factors. EV content appears to generate higher attention and discussion in descriptive terms, but the statistical results do not support strong conclusions about the superiority of one powertrain category over another. Instead, the results indicate that creators should distinguish between different engagement goals: reach, positive feedback and discussion intensity. For automotive brands and content creators, this means that content strategies should not focus only on EV-related topics, but should consider a balanced portfolio of EV, hybrid and ICE content, adjusted according to the desired audience response.

5 Conclusion

This study examined audience engagement with YouTube automotive review videos focused on electric, hybrid and internal combustion engine vehicles. The analysis was based on 75 videos published by five established automotive content creators. The study compared selected engagement indicators, including views, likes, comments, video length, combined engagement and recognizability of the powertrain type before clicking on the video.

Descriptive findings showed that EV videos achieved the highest average normalized view performance and the highest number of comments per 10,000 views. This suggests that EV-related content may currently attract higher attention and stimulate more discussion than hybrid and ICE content. However, the Kruskal-Wallis tests did not confirm statistically significant differences between ICE, EV and hybrid videos in views, likes, comments or combined engagement. Therefore, the observed differences between powertrain categories should be interpreted as descriptive tendencies rather than statistically confirmed differences.

The results also showed that video length is an important content-related factor. Longer videos were associated with lower normalized view performance, but with higher engagement intensity. This indicates that shorter videos may be more suitable for maximizing reach, while longer videos may be useful when the aim is to generate deeper audience involvement, discussion and feedback. The analysis also found a strong negative relationship between normalized views and combined engagement per 1,000 views, suggesting that higher reach does not automatically lead to higher engagement intensity. For this reason, automotive content performance should be evaluated using multiple metrics rather than view counts alone.

The recognizability of the powertrain type before clicking was also examined. Although videos in which the powertrain type was recognizable achieved higher average normalized views, the difference was not statistically significant. This suggests that clearly communicating the powertrain type may support content positioning, but it should be combined with other factors such as attractive titles, thumbnails, model relevance and publication timing.

From a practical perspective, the findings suggest several recommendations for automotive content creators and brands. First, creators should not rely only on the powertrain category as the main driver of performance, since the statistical tests did not confirm significant differences between EV, hybrid and ICE videos. Second, creators aiming to maximize reach should prioritize concise, information-rich videos. Third, longer and more detailed videos may be useful when the goal is to stimulate discussion and engagement among a more involved audience. Fourth, creators should evaluate content success through several indicators, including views, likes, comments and combined engagement, because each metric captures a different form of audience response.

The study has several limitations. The sample was exploratory and included 75 videos from five selected European automotive content creators. The analysis did not control for thumbnail design, title structure, creator-specific audience characteristics, brand popularity, model novelty, publication timing or broader media context. In addition, sentiment analysis of comments was not conducted, meaning that comment activity could not be classified as positive, negative or neutral. Future research should therefore use a larger dataset, include more creators and countries,

examine additional content characteristics, and apply sentiment analysis to better understand the nature of audience reactions to EV, hybrid and ICE content.

Overall, the study contributes to a better understanding of how automotive content performs in digital media environments. While EV content appears to attract higher attention and discussion in descriptive terms, the statistical findings suggest that engagement is influenced by a broader set of factors. For future research and practice, it is therefore important to examine not only what type of vehicle is reviewed, but also how the content is presented, structured and positioned toward the audience.

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ARTIFICIAL INTELLIGENCE AS A CATALYST FOR SOCIAL ENTREPRENEURSHIP AND VOLUNTEERING ENGAGEMENT

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Social entrepreneurship often emerges from grassroots volunteering driven by solidarity and local knowledge. Against the backdrop of rapid technological change, artificial intelligence (AI) acts as a catalyst, converting voluntary engagement into scalable social innovations. This paper explores how AI facilitates the transition from informal volunteering to structured social entrepreneurship models that stimulate economic development and job creation. Drawing on social innovation theory and the RBV, the study analyzes how AI tools - such as skill-matching algorithms, predictive models for community needs, and digital impact measurement platforms - enhance organizational capacity and social inclusion. The paper further examines governance and ethical implications, arguing that AI-driven social entrepreneurship can support ESG transformation when technological innovation remains aligned with solidarity and human-centered development. By integrating AI, grassroots initiatives transcend traditional boundaries, creating sustainable value and fostering inclusive growth in the digital era.

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1 Introduction

Grassroots volunteering has long been a foundational mechanism for addressing unmet social needs, fostering solidarity, and strengthening local communities. Historically, many social enterprises have emerged from informal volunteer initiatives driven by civic engagement and collective responsibility. While volunteering generates social value and mobilizes human capital, it often remains constrained by limited scalability, fragmented coordination, and insufficient resource optimization. In this context, “individuals, community groups, and organisations step in, supporting and complementing governmental efforts through entrepreneurial, volunteer or other kinds of initiatives - sometimes even taking over certain social functions traditionally performed by state institutions” (Vasilska, 2025). This dynamic illustrates how civic engagement increasingly extends beyond complementary action and evolves toward structured social initiatives.

In parallel, contemporary societies are undergoing rapid digital transformation, characterized by the expansion of Artificial Intelligence (AI), big data analytics, and algorithmic decision-making. While AI is predominantly associated with corporate efficiency and industrial automation, its transformative potential within the social and solidarity economy remains underexplored. The integration of AI into socially oriented organizations creates new opportunities for scaling impact, enhancing inclusion, and improving evidence-based decision-making.

This paper argues that AI functions as a strategic catalyst in the transition from informal volunteering engagement to structured models of social entrepreneurship. By enabling intelligent skill-matching, predictive identification of community needs, and automated impact measurement, AI transforms dispersed voluntary energy into coordinated, sustainable, and economically viable social innovation. Drawing on social innovation theory, the resource-based view (RBV), and the social and solidarity economy framework (SSE), the study develops a conceptual model explaining how AI enhances organizational capabilities, supports the inclusion of marginalized groups, and contributes to employment generation within socially driven enterprises.

The contribution of this paper is: 1) it bridges the literature on volunteering and social entrepreneurship through a digital transformation perspective; 2) it conceptualizes AI as a dynamic capability within mission-driven organizations; 3) it situates AI-enabled social entrepreneurship within the broader ESG and sustainable governance discourse, emphasizing the importance of human-centered and ethically grounded technological adoption. This paper is theoretical in nature and does not include empirical testing, but it proposes a structured conceptual framework to guide future research. Its main conceptual contribution lies in positioning AI not only as a digital tool for improving organizational efficiency, but as a socio-technical and institutional enabler that supports the transformation of volunteering into structured social entrepreneurship. In this way, the paper advances existing literature by linking volunteer-based civic engagement, AI-supported capability building, and ESG-oriented governance within one integrated conceptual framework.

2 Theoretical framework

This study builds its analytical foundation on three complementary theoretical perspectives: social innovation theory, the RBV, and the social and SSE framework. These perspectives allow for a multidimensional understanding of how grassroots volunteering initiatives evolve into structured social entrepreneurship models, and how AI can act as a catalytic enabler within this transition. Social innovation theory provides insight into the emergence and scaling of socially oriented solutions; the RBV explains how organizational capabilities and intangible assets generate sustainable value; and the SSE framework situates these processes within a normative context of collective welfare, inclusion, and democratic governance. By integrating these lenses, the study conceptualizes AI not merely as a technological tool, but as a strategic and institutional infrastructure that strengthens the transformation of voluntary engagement into economically viable and socially impactful enterprises.

2.1 Social innovation theory

Social innovation refers to the development and implementation of new ideas, practices, services, or governance arrangements that address unmet social needs and generate societal value beyond purely economic returns (Ünlü & Rao-Nicholson, 2026). Unlike conventional innovation, which is often assessed primarily in terms of

technological advancement or profitability, social innovation is oriented toward social welfare, inclusion, and systemic improvement. Importantly, recent conceptualizations emphasize that social innovation can be embedded within technological innovation and may combine social purpose with revenue-generating models, thereby blurring the traditional boundary between non-profit and market-based approaches (Ünlü & Rao-Nicholson, 2026).

The non-profit sector has historically functioned as a key source of social innovation. Non-governmental organizations often experiment with new approaches to mitigating social problems, mobilizing communities, and complementing state action in areas where public intervention is insufficient (Safarov, 2025). He highlights structural constraints that limit the scalability of such innovations, including tight budgetary conditions, fragmented ecosystems, and weak coordination between donors, beneficiaries, and innovation developers. These limitations create a structural gap between grassroots problem-solving and sustainable institutionalization.

Volunteering plays a critical role within this landscape. Research demonstrates that volunteering can extend beyond service production and contribute directly to social innovation processes, particularly when volunteers participate in idea generation, implementation, and diffusion of new practices (de Wit et al., 2017). In this sense, volunteering constitutes an upstream phase of social innovation - an incubation environment where needs are identified and solutions are tested. Yet, as de Wit et al. (2017) argue, without organizational structures that enable scaling and institutional learning, the impact of such initiatives often remains localized.

Recent ecosystem-oriented perspectives further expand this understanding. The Quadruple helix model, which integrates government, academia, industry, and civil society, underscores that systemic social innovation requires coordinated cross-sector collaboration rather than isolated initiatives (Ng, 2025). Fragmentation, asymmetry of resources, and institutional rigidities often hinder such collaboration (Ng, 2025). From this perspective, digital infrastructures - including AI-enabled platforms - can potentially act as integrative mechanisms facilitating data sharing, stakeholder coordination, and shared evaluation metrics.

Social innovation theory suggests that the transition from volunteering to social entrepreneurship depends not only on motivation and civic engagement, but also on mechanisms that enable coordination, scalability, and institutionalization. This creates a theoretical opening for considering AI as an infrastructural enabler of systemic social innovation.

2.2 Resource-based view (RBV)

The Resource-based view (RBV) posits that sustainable advantage derives from resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). While originally developed in the context of competitive firms, RBV has increasingly been applied to mission-driven organizations and social enterprises. In these settings, key strategic resources often include social capital, community trust, volunteer commitment, local knowledge, and legitimacy.

Empirical evidence from work integration social enterprises (WISEs) indicates that social innovation and competitiveness are closely linked to internal capability configurations that combine social mission and operational adaptability (Krejčí & Duháček Šebestová, 2025). In particular, innovation efforts that integrate employee development with product and service innovation contribute to both inclusion and economic sustainability. This illustrates how mission-driven organizations can leverage intangible assets to create hybrid forms of value.

From an RBV perspective, AI may be conceptualized as a strategic capability that enhances the effective utilization of existing resources. AI systems can support intelligent skill-matching between volunteers and tasks, predictive identification of emerging social needs, and automated impact measurement. Such functionalities increase the productivity of social capital and reduce coordination costs. In online volunteering contexts, volunteer experience has been shown to influence project completion rates and retention, with diminishing returns at higher levels of experience (Urrea & Yoo, 2022). AI-enabled systems can optimize task allocation by matching urgency, complexity, and volunteer experience, thereby increasing overall organizational performance.

Furthermore, volunteering is increasingly connected to human resource development and employability pathways (Kals et al., 2025). If supported by appropriate technological infrastructures, volunteer engagement can generate skill acquisition, certification, and professional spillovers. In this sense, AI becomes a dynamic capability that transforms dispersed voluntary contributions into structured organizational capital, strengthening the strategic position of social enterprises within the broader social and solidarity economy.

2.3 Social and solidarity economy (SSE)

The Social and solidarity economy (SSE) provides the normative and institutional context within which social innovation and social entrepreneurship operate. SSE organizations prioritize collective welfare, democratic governance, and reinvestment of surplus for social objectives. Economic viability is pursued not as an end in itself, but as a mechanism for sustaining social mission. Within this framework, social enterprises - particularly WISE models-serve as vehicles for integrating disadvantaged groups into the labor market (Krejčí & Duháček Šebestová, 2025). Social innovation supports these enterprises by introducing new organizational practices, inclusive employment models, and hybrid governance arrangements. However, as Safarov (2025) notes, limitations in social investment markets and coordination mechanisms may restrict their growth potential.

The Bulgarian experience provides a relevant institutional context for understanding the transition from volunteering to structured social entrepreneurship. The adoption of the Law on social and solidarity economy enterprises (2018) marked a significant step toward formalizing and recognizing social enterprises as distinct economic actors within the national legal framework. The law defines social enterprises, establishes criteria for registration, and introduces mechanisms for certification and public recognition, thereby creating a structured environment for organizations pursuing social objectives through economic activity. In practice, however, many socially oriented initiatives in Bulgaria still originate from grassroots volunteering, civic mobilization, and community-driven responses to social challenges. The regulatory framework offers institutional legitimacy and visibility, yet scaling remains constrained by limited financial instruments, fragmented support ecosystems, and insufficient digital infrastructure. In this context, AI may serve as a complementary governance and coordination tool - supporting transparent impact reporting, better

matching of vulnerable groups to employment opportunities, and more efficient resource allocation - thus reinforcing the objectives embedded in the national SSE legislation while enhancing its practical effectiveness. In this sense, the Bulgarian context illustrates a broader structural pattern in which formal regulatory recognition does not automatically translate into operational scalability. This gap reinforces the argument of the paper that AI can function as a bridging infrastructure between institutional frameworks and practical implementation, enabling more effective coordination, resource allocation, and impact measurement within social entrepreneurship ecosystems.

Digital transformation introduces new possibilities but also new risks. Evidence from corporate contexts suggests that AI adoption can improve ESG performance by enhancing transparency, reducing information asymmetry, and supporting evidence-based governance (Liu & Shen, 2025). Translating this insight into the SSE context implies that AI can strengthen accountability, improve impact reporting, and enhance stakeholder trust. At the same time, ethical considerations, such as algorithmic bias, digital exclusion, data governance, etc. must be addressed to ensure that technological adoption remains aligned with solidarity and human-centered principles.

Importantly, motivations for volunteering are themselves evolving. Research distinguishes between traditional value-driven motivations and reflexive motivations linked to self-development and career advancement (Frgelcová, 2025). AI-supported platforms can potentially respond to both motivational profiles through personalized engagement pathways, recognition systems, and skill-based progression structures. Such systems must avoid instrumentalizing volunteering in ways that undermine internal commitment.

The integrative perspective developed in this study is summarized in Table 1, which synthesizes the core contributions of the three theoretical pillars and their relevance to AI-enabled transformation.

Within this integrated framework, AI can be conceptualized as an enabling infrastructure that supports the transformation of grassroots volunteering into structured social entrepreneurship. By enhancing coordination, scalability, inclusion, and accountability, AI may catalyze the transition from localized solidarity actions

to sustainable, employment-generating social enterprises aligned with ESG-oriented governance.

Table 1: Integrative theoretical framework

Theoretical pillar	Core concept	Key mechanisms	Contribution to AI-enabled transformation
Social innovation theory	Emergence and scaling of socially oriented practices	Collaboration, systemic coordination, diffusion of innovation	Explains how volunteering initiatives generate new social practices and how AI enhances scalability and impact measurement
Resource-based view (RBV)	Strategic value of tangible and intangible resources	Volunteer skills, social capital, organizational capabilities	Conceptualizes AI as a dynamic capability that strengthens the strategic use of volunteer-based resources and improves efficiency
Social and solidarity economy (SSE)	Normative framework of inclusion and public value	Democratic governance, reinvestment of surplus, collective welfare	Anchors AI adoption in human-centered values and ensures that technological transformation supports inclusion and ESG objectives

Source: Author's conceptualization based on Social innovation theory, Resource-based view, and Social and solidarity economy literature.

3 AI as a factor for transforming volunteering

AI can be conceptualized as an enabling infrastructure that strengthens the transformation of volunteering from informal civic engagement into structured, scalable, and economically sustainable social action. Rather than replacing human solidarity, AI augments coordination, enhances learning processes, and reduces structural inefficiencies that often constrain grassroots initiatives.

3.1 Intelligent skill-matching and resource optimization

One of the most immediate contributions of AI lies in optimizing the allocation of volunteer resources. Research on online volunteering platforms demonstrates that volunteer experience significantly affects project completion rates and retention, although the effect diminishes at higher experience levels (Urrea & Yoo, 2022). This

suggests that effective task allocation and experience management are critical for performance.

AI-based skill-matching algorithms can analyze volunteer profiles, experience levels, availability, and task urgency to improve alignment between competencies and project needs. Such systems reduce coordination costs and increase completion rates, especially in contexts where urgency varies. From a RBV perspective, AI enhances the productive utilization of volunteer skills and social capital, transforming dispersed human effort into structured organizational capability.

In addition, as volunteering increasingly involves reflexive motivations - personal development and employability (Frgelcová, 2025) - AI-enabled platforms can personalize engagement pathways, recommend skill-building opportunities, and track competency development. This strengthens volunteer satisfaction while creating clearer transitions toward professional or entrepreneurial roles. For instance, digital volunteering platforms such as UN Volunteer Online Volunteering or matching platforms used by NGOs demonstrate how algorithm-based systems can improve alignment between volunteer skills and project needs.

3.2 Social needs – predictable identification

Moving beyond operational optimization, AI can contribute to identifying emerging social challenges. Predictive analytics tools can process large volumes of community data, detect patterns of vulnerability, and anticipate resource shortages. In the context of non-profit innovation ecosystems, limited coordination and fragmented information flows are often cited as barriers to scaling social innovation (Safarov, 2025).

By enabling real-time data integration across stakeholders - public institutions, civil society organizations, and social enterprises - AI can support earlier intervention and more targeted program design. Within the Quadruple helix framework (Ng, 2025), AI-driven platforms may function as shared infrastructures that connect government, academia, industry, and civil society actors around common data ecosystems.

In this sense, AI strengthens systemic responsiveness and reduces informational asymmetry, thereby facilitating a smoother transition from volunteer-driven initiatives to institutionalized social enterprises.

3.3 Impact measurement and accountability

A recurring limitation of grassroots volunteering is the difficulty of measuring social impact and demonstrating value to funders, policymakers, and beneficiaries. Social innovation often struggles with fragmented reporting systems and limited evaluation capacity (Safarov, 2025).

AI-enabled impact measurement platforms can automate data collection, monitor performance indicators, and generate transparent reports aligned with ESG criteria. Evidence from corporate contexts suggests that AI adoption may improve ESG performance by enhancing transparency and decision quality (Liu & Shen, 2025). Social enterprises operate under different institutional logics, similar mechanisms - improved data accuracy, reduced information asymmetry, and real-time reporting - can enhance legitimacy and trust within the social and solidarity economy.

AI-supported reporting tools used by social enterprises enable automated ESG reporting and real-time impact tracking. By strengthening accountability mechanisms, AI contributes not only to operational efficiency but also to governance quality.

3.4 From volunteer experience to entrepreneurial pathways

Volunteering is increasingly recognized as a site of skill development and human capital formation (Kals et al., 2025). When supported by structured organizational systems, volunteer engagement can generate professional competencies, networks, and leadership skills that feed into social entrepreneurship. In practice, some platforms already connect volunteering experience with employability pathways through digital badges and micro-credentials.

AI can facilitate this transition by:

- tracking accumulated experience;

- identifying entrepreneurial potential;
- connecting volunteers with incubators or funding opportunities;
- supporting digital credentialing and certification systems.

Such mechanisms are particularly relevant in contexts where social enterprises - such as work integration social enterprises (WISEs) - serve as vehicles for employment inclusion (Krejčí & Duháček Šebestová, 2025). AI-enhanced systems can match vulnerable individuals with suitable training and employment opportunities, reinforcing inclusion while improving enterprise sustainability.

AI operates as a structural bridge between volunteering and social entrepreneurship. It enhances the scalability of social innovation processes, strengthens organizational capabilities, and supports governance mechanisms aligned with inclusion and ESG objectives. The transformative potential of AI is contingent upon ethical design, transparent governance, and safeguards against digital exclusion - issues that will be addressed in the following section.

4 From volunteering to social enterprise: stages

The transition from grassroots volunteering to structured social enterprise does not occur automatically. It is a gradual process shaped by organizational learning, capability accumulation, institutional support, and increasingly, digital infrastructure. Based on the three theoretical pillars, the concept of transformation, structured as a multi-stage process, is summarized in Table 2, where the individual stages of transition from volunteering to social enterprise are systematized and linked to the catalytic role of AI.

The transformation from grassroots volunteering to structured social enterprise should not be interpreted as a strictly linear progression, but rather as a dynamic and iterative process characterized by feedback loops between stages. The transition between the identified stages is driven by several interrelated mechanisms. First, cumulative learning effects emerge as volunteers repeatedly engage in problem-solving activities, leading to the gradual development of organizational knowledge and routines. Second, capability consolidation occurs through the structuring of roles, processes, and governance arrangements, often supported by digital tools. Third, coordination efficiency increases as AI-supported systems enhance matching,

information flow, and decision-making processes. Finally, institutional pressures related to sustainability, legitimacy, and access to funding encourage formalization and the transition toward social enterprise models. These mechanisms highlight that the transformation process is not automatic, but dependent on organizational learning, technological integration, and institutional context. Even after formal institutionalization, social enterprises frequently continue to rely on volunteer engagement as a source of innovation, community embeddedness, and social legitimacy. Volunteering remains a mechanism for detecting emerging needs, testing solutions, and sustaining participatory governance practices. Sustainable transformation depends on continuous interaction among civil society, public institutions, academia, and industry. Innovation and institutional development therefore co-evolve within a broader ecosystem of actors.

Table 2: Stages of transformation from volunteering to social enterprise

Stage	Characteristics	Drivers	AI-enabled contribution
Stage 1: Civic mobilization	Grassroots engagement; identification of social needs; value-driven or reflexive motivations	Community solidarity; volunteer initiative; social awareness	Data aggregation and mapping of community needs; improved coordination and visibility
Stage 2: Social innovation experimentation	Pilot initiatives; collaborative problem-solving; informal structures	Iterative learning; network collaboration; resource improvisation	Intelligent skill-matching; predictive analytics; real-time feedback and digital documentation of impact
Stage 3: Organizational structuring	Formalization of roles; governance arrangements; capability consolidation	Accumulated knowledge; social capital; mission alignment	Workflow optimization; performance tracking; volunteer lifecycle management; competency tracking
Stage 4: Institutionalization as social enterprise	Economic sustainability; hybrid governance; employment inclusion	Business model development; stakeholder legitimacy; market integration	ESG-aligned impact reporting; predictive workforce inclusion models; transparent governance dashboards

Source: Author's conceptualization based on Social innovation theory, Resource-based view, and Social and solidarity economy framework, and AI transformation literature.

Within this evolving system, AI operates not as a one-time technological intervention but as an embedded infrastructural capability that supports coordination, learning, data integration, and accountability across the entire lifecycle of social enterprise development. AI-enhanced systems improve visibility of social needs, optimize experimentation processes, consolidate organizational capabilities, and strengthen transparency mechanisms aligned with ESG principles.

Conceptually, the mechanisms of transition can be summarized sequentially as follows: (1) civic mobilization generates social awareness and collective engagement around unmet needs; (2) social innovation experimentation produces novel solutions through collaborative and iterative problem-solving; (3) organizational structuring consolidates capabilities, formalizes governance arrangements, and enhances operational efficiency; (4) institutionalization enables the creation of sustainable social enterprise models that combine economic viability with social mission.

Across these interconnected stages, AI enhances coordination, scalability, accountability, and inclusion, thereby accelerating the transformation of voluntary engagement into structured social entrepreneurship aligned with ESG-oriented governance and long-term public value creation.

5 Governance, ethics and ESG implications

The integration of AI into volunteering ecosystems and social enterprises introduces significant governance implications; it also raises concerns related to transparency, accountability, and algorithmic bias. This transformation introduces new layers of institutional responsibility. While AI systems enhance analytical capacity and operational consistency, they also redistribute decision-making power toward algorithmic processes. In mission-driven organizations working in the social and solidarity economy, redistribution requires careful oversight to prevent opacity, concentration of information control, and reduced participation in discussions.

Empirical evidence indicates that AI adoption may contribute to improved ESG performance through enhanced data accuracy and decision quality (Liu & Shen, 2025). Within the context of social enterprises, governance quality extends beyond informational efficiency to include procedural fairness and mission coherence. Algorithmic systems embedded in volunteer allocation, workforce inclusion, or

impact assessment may unconsciously prioritize measurable outcomes over social complexity. This dynamic generates a governance tension between quantification and mission integrity.

At the same time, evolving motivational structures in volunteering require institutional sensitivity. Performance monitoring mechanisms, ranking systems, automated evaluation tools may improve coordination yet simultaneously reshape the normative foundations of voluntary participation. Governance arrangements must therefore ensure that digital infrastructures reinforce, rather than instrumentalize, civic commitment.

From an ESG perspective, the central implication lies in institutionalizing responsible AI within solidarity-based economic models. Essential conditions become transparent data governance, inclusive algorithm design, participatory oversight mechanisms, and alignment with public value objectives. Sustainable governance in AI-enabled social enterprises is thus determined not solely by technological capability, but by the degree to which digital systems are embedded within democratic, human-centered institutional frameworks.

6 Discussion

The integration of AI into volunteering ecosystems and social entrepreneurship raises several critical questions that extend beyond operational efficiency and technological optimization. At the conceptual level, an important issue concerns the extent to which AI-mediated coordination reshapes the nature of civic engagement itself. If digital infrastructures increasingly structure how volunteers are matched, evaluated, and retained, does this transformation enhance collective capacity, or does it gradually redefine volunteering in more instrumental and performance-oriented terms? This study contributes to the literature by conceptually linking micro-level volunteer engagement with macro-level institutional transformation through AI-supported coordination, capability development, and ESG-oriented governance mechanisms.

A second question relates to capability formation and power distribution. When AI becomes embedded in decision architectures: allocating tasks, predicting needs, and structuring impact measurement. So, who ultimately controls the underlying data

and algorithms? Does the concentration of informational power risk weakening participatory governance within solidarity-based organizations, or can algorithmic systems be designed in ways that reinforce transparency and collective oversight?

A further discussion point concerns the balance between scalability and mission integrity. While digital systems enable rapid growth and measurable outcomes, social enterprises operate within normative commitments to inclusion, dignity, and democratic participation. Can AI-driven models of coordination and reporting preserve these commitments under conditions of expansion, or do they introduce pressures toward standardization that may marginalize context-specific social realities?

Finally, the relationship between AI and employment inclusion warrants closer examination. If AI supports more efficient workforce integration and entrepreneurial pathways, under what conditions does this lead to genuine empowerment rather than conditional participation governed by data-driven performance thresholds? How can AI-enabled social enterprises ensure that technological mediation strengthens long-term social mobility rather than reproducing structural inequalities?

The consequences of AI adoption in volunteering and social entrepreneurship depend on how digital systems are governed, interpreted, and steered by human actors. AI does not operate autonomously within solidarity-based ecosystems; its outcomes are shaped by managerial choices, institutional oversight, and the capacity of organizations to retain human judgment at the center of decision-making processes.

7 Conclusion

This paper has explored the transformation of volunteering into structured social entrepreneurship through the lens of AI as an enabling infrastructure. The analysis has shown that grassroots civic engagement, while rich in solidarity and local knowledge, often faces limitations related to scalability, coordination, and institutional sustainability. AI has been conceptualized as a mechanism capable of strengthening these dimensions by enhancing resource allocation, supporting data-driven decision-making, and facilitating organizational consolidation.

The transformation process was examined as a dynamic, multi-stage trajectory in which civic mobilization evolves into social innovation, organizational structuring, and ultimately institutionalized social enterprise. Across these stages, AI contributes by improving coordination, strengthening capabilities, and reinforcing accountability mechanisms. At the same time, the analysis emphasized that technological integration must remain embedded within solidarity-based values, democratic governance, and human-centered decision-making.

The discussion highlighted that AI does not autonomously determine outcomes in volunteering or social entrepreneurship. Its impact depends on how digital systems are designed, governed, and managed by human actors. Responsible integration requires transparency, participatory oversight, and alignment with broader public value objectives. When embedded within such frameworks, AI can accelerate inclusive economic participation, support employment creation, and enhance governance quality within the social and solidarity economy.

In this sense, AI represents neither a replacement for civic engagement nor a purely technical upgrade, but a structural catalyst whose transformative potential unfolds only when guided by deliberate institutional design and ethical management.

As a conceptual study, this paper does not aim to provide empirical validation or case-based evidence. Instead, it offers a structured theoretical framework that can serve as a foundation for future empirical research and practical applications in the field of AI-driven social entrepreneurship and volunteering ecosystems. In this way, the study provides a foundation for understanding how AI can be strategically embedded in social innovation ecosystems to support sustainable and inclusive development.

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DIGITAL LAG OR SUSTAINABLE LEAP? STRATEGIC PATHS FOR EMERGING ECONOMIES IN THE AI AGE

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This study analyses the strategic dilemma facing emerging economies in the context of the accelerated penetration of artificial intelligence (AI): will it lead to digital dependency, or will it become a catalyst for a sustainable structural leap? In response, a mediation analytical model (of mediated and contingent dependencies) is developed that links AI readiness, institutional capacity, and the degree of ESG integration with digital competitiveness and structural transformation. The study argues that AI's direct impact on the levels of economic development of a system is unstable and partial. Its impact is expressed through the activities of institutions and is conditional on the strategic integration of sustainability principles. Two alternative models (configurations) are identified: fragmented digitalization, leading to limited added value, and coordinated AI integration, supporting increased economic complexity and long-term sustainability. The article contributes to the literature by providing a contingent analytical model for studying AI-mediated structural transformation.

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1 Introduction

Today, the global economy is operating in a new stage of technological transformation, marked by the accelerated introduction of artificial intelligence (AI) as a fundamental technology with widespread application. Unlike previous stages of digitalization, which focused on automation and achieving information connectivity, the current stage is associated with algorithmic autonomy, predictive modelling, and transformation of decision-making processes. Data from international sources (e.g. the Stanford AI Index, IMD, OECD) show a clear concentration of investments in AI, increased research and innovation activities, mainly in a limited circle of highly developed countries, which raises the risk of deepening global digital asymmetries (Ivanov, 2022).

The question of whether AI can support catch-up development or reinforce existing inequalities cannot be answered through a purely technological lens. Historical evidence from previous technological revolutions suggests that their economic impact depends on institutional quality, strategic coordination, and governance capacity. In this environment, developing economies find themselves in a particularly vulnerable position. On the one hand, AI creates the potential for “step-skipping” through direct integration of high-tech solutions. On the other hand, dependence on external technology providers, limited R&D capacity, human capital deficits, and weak institutional capacity can make AI a factor in deepening structural vulnerability. This outlines the main strategic challenge, the focus of this study: under what conditions does AI act as a catalyst for sustainable structural transformation, and when does it reinforce peripheral positioning in the global economy?

Existing literature typically addresses AI in three dimensions: 1) impact on productivity and innovation; 2) measurement of digital competitiveness; and 3) sustainable governance and ESG policies. However, an integrated analytical framework is lacking that simultaneously considers AI as a technology of general application and analyses the role of ESG-oriented strategies as a factor determining the long-term impact on competitiveness and structural transformation. This study positions itself precisely in this theoretical gap.

The main thesis of this study is that the impact of AI on the digital competitiveness and structural dynamics of developing economies depends on the interaction between technological readiness, institutional capacity and the degree of integration of sustainable development goals. The study is based on theoretical analysis and comparative research through secondary analysis of international indicators for AI readiness, digital competitiveness and sustainable development. Its aim is to develop a concept of an integrated model that explains the conditions under which AI acts as an accelerator for achieving sustainable economic and social development. In this context, the main research questions are:

- Under what conditions can AI help overcome structural constraints in developing economies?
- How do ESG-oriented strategies influence the long-term impact of AI on digital competitiveness?
- What is the role of institutional capacity as a bridge between technological integration and sustainable development?
- Is there a realistic possibility of achieving a “sustainable digital leap”, or will technological dependency continue to deepen?

This paper makes three specific contributions: 1) conceptualizes the notion of a “sustainable digital leap” as an alternative to dependency-driven digitalization; 2) integrates AI readiness, institutional capacity, and ESG orientation into a unified analytical framework; 3) develops a mediation model that explains how AI influences structural transformation through institutional transmission and sustainability conditions. Since the analysis is based on aggregated international indices, it does not cover sectoral and regional differences in individual economies, nor does it provide a quantitative test of the proposed causal logic. Regardless of these limitations, the developed framework offers a tool for strategic understanding of the role of AI in the long-term trajectory of emerging economies.

2 Theoretical Framework: AI between Dependence and Sustainable Development

This research is based on the understanding that artificial intelligence is not just a new technological tool, but part of a broader transformation that impacts the structure of the economy, value creation models, and institutional governance

mechanisms. AI operates as a potential catalyst for catch-up development and as a factor in deepening existing asymmetries. This dual role leads to the need of integration of three theoretical perspectives: 1) digital competitiveness and structural constraints facing developing economies, 2) ESG framework as a strategic mechanism for managing technological transition, and 3) alternative development trajectories – fragmented digitalization vs. coordinated strategic integration.

2.1 Digital competitiveness and structural constraints

Digital lag as a structural phenomenon

The concept of “digital lag” goes beyond the classic concept of “digital divide”, which focuses on infrastructural access to the Internet and ICT. In the contemporary context, the key issue is not only the availability of technologies, but also the ability of the economy to integrate them productively into production processes, services and public governance. As van Dijk (2020) and OECD (2023) emphasize, the transformational effect of digitalization depends on the quality of use of the implemented technologies, institutional readiness and the degree of strategic coordination. Digital lag could be defined as a structural inability to transform technological investments into sustained productivity and innovation outcomes. It often leads to the reproduction of a peripheral model of participation in global value chains, limited to low-tech activities and minimal innovation autonomy (UNCTAD, 2023).

Brynjolfsson, Rock and Syverson’s (2021) analysis of the “productivity paradox” shows that large investments in digital technologies do not automatically lead to measurable productivity gains. Positive returns depend on complementary organizational changes, new business models, and skills accumulation. Digitalization therefore functions as a conditional factor of growth, the outcome of which depends on the availability of complementary institutional and organizational resources. From a macroeconomic perspective, international digital competitiveness indices (IMD, WEF) show a concentration of digital capabilities in economies with high institutional quality, an innovation ecosystem and significant investments in human capital. Developing countries lag primarily due to limited systemic integration of digital solutions into the industrial and public structure.

Institutional capacity and technological dependence

In the context of institutional economics, North (1990) argues that sustainable growth is a function of stable and predictable institutional rules that reduce transaction costs and encourage investment in innovation. In AI-driven economies, this principle extends to data governance, transparency, and regulation of digital markets presuppose a high degree of institutional competence.

Acemoglu and Robinson (2012) emphasize that a strong institutional base is a prerequisite for sustainable technological development, while extractive institutional structures can concentrate the benefits of innovation in limited groups. In the context of AI, this is manifested through the global concentration of computing resources, patents and digital platforms in a small number of countries and corporations. UNCTAD (2023) data show that the majority of investments in AI are directed to a few developed economies, which limits the opportunities for autonomous development of technological capacity in peripheral countries. This asymmetry creates a risk of forming a “digital dependency trap”, in which developing economies remain mainly users of foreign technologies and platforms, without the opportunity to build their own research and innovation base. Rodrik (2011) emphasizes the role of coordinated industrial policy in the process of technological catch-up. In the AI context, this requires coordinated interaction between state, business and academia, aimed at creating local capacity, rather than fragmented implementation of external solutions.

Institutional alignment creates the enabling environment, but it is organizational strategic capacity that determines whether AI translates into measurable competitive gains. In this sense, digital transformation represents the structured integration of human, informational, and organizational capital into a coherent strategic architecture that converts intangible capabilities into sustained performance outcomes (Tanushev, 2022).

Digitalization, value added and economic complexity

Artificial intelligence is seen as a general-purpose technology (Aghion, Antonin, & Bunel, 2023), capable of transforming multiple sectors simultaneously. Historically, such technologies generate delayed and institutional-dependent productivity effects.

Perez's (2002) theory of technological revolutions shows that new technological paradigms initially enter an environment with a clear institutional incompatibility, which requires regulatory and organizational transformation. Empirical analyses by OECD (2022) confirm that enterprises that combine investments in digital technologies with skills development and organizational reform achieve higher productivity growth than those that implement technologies as an isolated management solution. Therefore, the relationship between digitalization and added value is not linear. Automation without structural upgrading does not increase economic complexity. The World Bank (2021) emphasizes that data and digital technologies generate public value only in the presence of effective governance, transparent rules and public trust.

Digital competitiveness thus emerges as a systemic outcome of technological capability, institutional quality and value-creation capacity. Structural constraints in developing economies arise from the interaction between technological gaps and weak institutional coordination. This interdependence leads to the need to examine EGS as a strategic mechanism shaping AI-driven transformation.

2.2 ESG as a strategic framework for sustainable transition

ESG principles initially emerged in the context of corporate governance as a tool for assessing non-financial risks and the sustainability of companies (Elkington, 1998) (Eccles & Strohle, 2018). With the development of global capital markets and regulatory standards, ESG has gradually transformed from a reporting framework into a broader strategic framework that influences capital allocation, investment priorities and institutional design (Friede, Busch, & Bassen, 2015) (OECD, 2022). ESG functions as a strategic coordination mechanism shaping incentives, risk management, and allocation of innovation resources.

In the context of accelerated AI transformation, this functionality is particularly important. Artificial intelligence can increase productivity and efficiency, but at the same time it also carries risks of concentration of market power, automation of labor, algorithmic discrimination and significant energy consumption (OECD, 2025) (UNESCO, 2021). Without appropriate governance mechanism, these externalities can amplify social and structural imbalances.

ESG therefore functions as a mediator in three main directions:

- 1) allocational – by directing investments towards sustainable technological solutions;
- 2) regulatory – by institutionalizing standards for transparency, accountability and data management;
- 3) legitimization – by creating public trust and social acceptability of digital transformation.

Empirical observations from global supply chains suggest that ESG frameworks frequently emerge as self-regulatory substitutes in contexts of weak or fragmented public governance, particularly in emerging economies (Boeva, 2015). Initiatives such as the OECD Principles on AI and regulatory frameworks such as the European Union's AI Act show that AI governance is gradually being integrated into a broader logic of responsible and sustainable innovation. This does not mean that ESG automatically guarantees a balanced transition, but it does show that technological developments are increasingly being assessed through the prism of institutionalized responsibility.

Integrating technological development with sustainability principles

The theory of “creating shared value” (Porter & Kramer, 2018) argues that economic efficiency and social impact can be mutually reinforcing when strategic decisions are oriented towards creating long-term value for the system. In the AI context, technological policy must be embedded within broader development strategies. The integration of technological development and sustainability principles implies institutional coordination between industrial policy, education system, data regulations and environmental standards. The World Bank (2021) emphasizes that data generates public value only when there are clearly defined rules for access, protection and sharing, while UNDP (2022) notes that digital transformation contributes to the achievement of the Sustainable Development Goals (SDGs) only if it is integrated into national strategic frameworks.

From an analytical perspective, this means that ESG does not change the technological capability of the economy itself, but the way it is directed and structured for use. While institutional capacity determines the possibility of AI

integration, the ESG framework influences the direction of that integration – whether it will focus on short-term efficiency or on increasing economic complexity, social connectivity and accessibility, and environmental sustainability.

"Sustainable digital leap" as institutional alignment

The concept of a “sustainable digital leap” can be described as a process of alignment between technological innovation, institutional design and sustainability goals, in which AI is used to overcome structural constraints rather than to reproduce them. The classic theory of catch-up development (Gerschenkron, 1962) suggests that partial economic backwardness can be compensated by rapid adoption of available technologies. In the AI context, however, adoption without institutional alignment creates the risk of dependency and limited generation of added value. Perez (2002) shows that technological revolutions require new institutional alignment to move from a diffusion phase to a sustainable development phase.

In these conditions, the sustainable digital leap is not seen as a quantitative expansion of the number of AI projects, but as a qualitative transformation of the economic structure by building innovation capacity, increasing technological sophistication and strengthening social cohesion. In this framework, ESG plays the role of a mediator, bringing out the factors that lead to the integration of AI into the economy, reducing the likelihood that it will become a source of asymmetric dependence. Viewed in this way, the sustainable digital leap represents an alternative direction of development in which technological transformation is institutionally directed and strategically coordinated. This allows for an analytical distinction between superficial digitalization (limited to the implementation of technologies) and structural modernization based on synchronization between AI, institutional capacity and sustainability orientation.

2.3 The dual path of development: fragmented digitalization versus strategic integration

The penetration of AI into developing economies does not follow a universal or technology-driven path. Its trajectory depends on the configuration of technological readiness, institutional capacity, and strategic alignment. Within this framework, two analytical models can be distinguished: 1) fragmented, reactive digitalization and 2) coordinated, institutionally aligned AI integration.

Model I: Fragmented and reactive digitalization

The first model is characterized by partial and unsynchronized implementation of AI in individual sectors or organizations. Digitalization emerges as a reactive response to external pressure (international competition, regulatory requirements or requirements of global investors) without the presence of an integrated national vision (including strategy). In such an environment, technological solutions are applied sectorally (fragmentarily), without connection with the education system, industrial policy or strategic data management. The lack of a “whole-of-government” approach (OECD, 2025) leads to limited return on public investments and a low degree of technological diffusion in the economy. The absence of synchronization between technological implementation and human capital development limits the possibility of creating internal innovation capacity. As a result, economy remains dependent on external platforms and software ecosystems, with local added value concentrated in adaptation and service, rather than in the creation and development of technologies.

Empirical observations by UNCTAD (2023) and the World Bank (2021) show that in a number of developing economies, digital technologies are used primarily to optimize existing processes, without leading to a targeted and appropriate change in the production structure. This leads to entrenchment in peripheral segments of global value chains and limited economic complexity. In the absence of ESG integration, the risks resulting from the implementation of fragmented digitalization are amplified: investments are directed towards short-term efficiency, without including structural transformation.

Model II: Coordinated and strategically aligned AI integration

The alternative model assumes the presence of a long-term AI strategy, integrated with the implemented industrial policy, the education system, the research infrastructure and the regulatory system. In this case, the institutional capacity acts as a mediator between technological innovation and the transformation of the economic structure (North, 1990) (Rodrik, 2011). Coordinated integration includes the development of local innovation ecosystems, investments in STEM education, data management as a strategic resource and the construction of computing infrastructure. AI is perceived and used as a horizontal infrastructure that

reorganizes production processes, public services and management practices (Aghion, Antonin, & Bunel, 2023). In this scenario, the ESG framework performs an operational function. It influences:

- the choice of investments, directing resources towards solutions with a long-term social impact;
- the regulatory system, through requirements for transparency, accountability and data protection;
- the social legitimacy of the digital transformation, which reduces the risk of institutional and public resistance.

In such a configuration, AI can contribute to increasing economic complexity, creating local technological capacity and improving the quality of public governance. However, it should be noted that coordinated integration is not automatically a guaranteed success. Insufficient administrative capacity, the lack of an adequate national development strategy or ineffective industrial policy can limit the transformative potential of AI, even in the presence of strategic documents for its implementation and use. Therefore, sustainable results depend on the real functioning of institutions, not on their formal existence.

The main distinction between the two models lies in the mode of institutionalization of AI. In fragmented systems, technological adoption reproduces existing structural constraints, whereas in coordinated frameworks, AI is integrated into broader strategies of structural modernization. This forms the basis of the analytical model, considering AI as a conditional tool, the long-term impact of which on competitiveness and structural dynamics depends on the quality of management and the degree of strategic integration.

3 Methodological approach

The present study applies a **conceptual-comparative approach**, combining theoretical synthesis with secondary analysis of international indicators and strategic documents. This choice reflects the complex and context-dependent nature of the relationship between AI integration, institutional capacity, ESG orientation, and digital competitiveness. Accordingly, the study develops an integrated framework

aimed at explaining the structural conditions under which different development trajectories (fragmented digitalization or coordinated strategic integration) emerge.

3.1 Research foundation and design

The methodological framework is based on an interdisciplinary synthesis between: (i) the theory of technological paradigms and the need for institutional compliance in technological revolutions (Perez, 2002), (ii) institutional economics and the role of rules and organizational incentives for sustainable growth (North, 1990), (iii) the theory of inclusive institutions and the risk of concentration of the benefits of technological progress (Acemoglu & Robinson, 2012), and (iv) the literature on digital competitiveness and the systemic factors of digital leadership (IMD; OECD).

The approach used can be seen as a form of scenario modelling, within which the identified structural determinants serve as a basis for building ideal-typical configurations outlining alternative development trajectories. The conceptual analysis performs three functions:

- 1) deduces the mediating role of institutional capacity between AI readiness and economic outcomes (North, 1990);
- 2) justifies ESG orientation as a strategic moderating mechanism that directs technological integration towards sustainable outcomes (OECD, 2022) (Porter & Kramer, 2018);
- 3) formalizes the interrelationships in a model “AI – Institutional Capacity – ESG – Digital Competitiveness”, which serves as a basis for typology of scenarios.

The comparative analysis follows the logic of a structural-typological approach used in comparative political economy to identify sustainable institutional configurations (Hall & Soskice, 2001). The comparative procedure is non-econometric and configurational, relying on relative positioning and pattern identification rather than statistical inference. The procedure involves three sequential steps:

First, countries (or groups of countries) are ranked along three dimensions: (1) AI readiness and technological/institutional readiness; (2) digital competitiveness as a systemic outcome; (3) sustainability and governance compliance as a proxy for ESG integration. The distinction between high-income and developing economies is

based on World Bank and IMF classifications, with the aim of identifying systemic differences in the structural parameters of the digital transition.

Second, the compatibility and imbalances between the dimensions are analysed, i.e. whether high values on the AI dimension coincide with institutional efficiency and sustainability orientation, or configurations of “technological dynamics without institutional alignment” are observed. In this context, compatibility is interpreted as the degree of alignment between technological capacity, institutional quality, and sustainability orientation, while imbalances refer to asymmetric configurations across these dimensions. The indicators are used as signals for structural mismatches relevant to the risk of dependency or the potential for structural leapfrogging (Acemoglu & Robinson, 2012).

Third, based on the configurational reading, ideal-typical scenarios are formulated, corresponding to the two models from the theoretical framework: a) fragmented, reactive digitalization (high dependence on external technological ecosystems, limited institutional capacity, weak sustainable integration); b) coordinated strategic integration (institutional alignment, investments in human capital and data, sustainability orientation and regulatory accountability). These scenarios are constructed as analytical configurations derived from consistent patterns of alignment or misalignment across the examined dimensions. Qualitative analysis of strategic documents complements indicator observations and allows for an assessment of the degree of policy coordination and regulatory maturity.

3.2 Indicator dimensions and sources used

The empirical grounding of the methodological framework is based on secondary data from internationally recognized indices and reports. The selection of indicators follows a structured logic aimed at capturing three distinct analytical layers: input capacities, institutional mediators, and systemic outcomes. Rather than being used for econometric estimation, the indicators serve as comparative proxies that enable the identification of structural patterns and configurational relationships across economies

Indicators for assessing AI readiness and AI capacity

The Government AI Readiness Index (Oxford Insights) is used as a proxy indicator of institutional and regulatory readiness for AI implementation in the public sector, including data infrastructure and human capital. The focus of the study is that the index captures not only the technological level, but also the degree of strategic coordination and management maturity.

The Stanford AI Index Report provides data on investments, scientific output, patents, start-ups and industrial deployment, which allows to assess the **real innovation activity** and concentration of AI capacity globally (Stanford Institute for Human-Centered Artificial Intelligence (HAI), 2024). The combined use of these two sources enables a distinction between **potential/readiness** and **actual innovation dynamics**, especially relevant for developing economies.

Indicators measuring digital competitiveness as a systemic outcome

The IMD World Digital Competitiveness Ranking is used as a key indicator of the systemic ability of economies to transform digital capacity into competitive advantage through components that combine knowledge, technological environment and future readiness.

Additionally, digital components of the **World Economic Forum – Global Competitiveness** (e.g. ICT adoption, innovation capability, skills) are used, as well as the **OECD Digital Economy Indicators**, which provide empirical support for the relationship between digital intensity, skills and productivity (World Economic Forum, 2019) (OECD, 2020). These sources are used in a complementary manner to enable comparative positioning and to identify persistent structural differences across economies.

Indicators measuring ESG integration, sustainability and quality of governance

In this article, ESG is not treated as a corporate rating, but as the degree of sustainability integration and institutionalized responsibility in national strategy. Therefore, a combination of proxy measures is used:

- **SDG Index** as an indicator of effective sustainability and compatibility between development and socio-environmental goals (Sachs, Lafortune, Fuller, & Drumm, 2023);
- **World Bank Worldwide Governance Indicators (WGI)** as a measure of institutional quality (rule of law, control of corruption, regulatory effectiveness, government efficiency), relevant to the state's ability to manage technological transition (Acemoglu & Robinson, 2012);
- **Strategic and regulatory documents** (national AI strategies; European Commission documents, including the AI Act; OECD AI Principles, 2019; UN/UNDP/UNESCO frameworks), used to qualitatively assess coordination, regulatory maturity and institutional priorities.

Model logic

Combining the indicators builds an integrative analytical framework that simultaneously assesses:

- 1) AI readiness/capacity as an input variable;
- 2) institutional capacity and governance quality as a mediator;
- 3) ESG integration as a strategic moderator;
- 4) digital competitiveness and sustainable outcome as output dimensions.

The framework allows for the identification of typological configurations, for example:

- economies with relatively high AI dynamics with low governance efficiency and limited sustainability compatibility (increased risk of dependency and social externalities);
- economies with technological intensity but weak institutional capacity (vulnerability to “locked-in” specialization);
- configurations of synergy between AI integration, institutional quality and sustainability orientation, corresponding to a scenario of coordinated strategic integration.

In this way, the indicators do not function as stand-alone statistical measures, but as interconnected elements of the methodology, which helps to distinguish a digital dependency scenario from a sustainable digital leap scenario.

Several **limitations** should be explicitly acknowledged. First, the indices used are aggregated composite measures and may mask intra-regional and sectoral differences. Second, the dynamics of AI are accelerating, and some indicators may lose explanatory power in the short term (Stanford Institute for Human-Centered Artificial Intelligence (HAI), 2024). Third, the chosen design does not provide econometric verification of causal relationships; the results should be interpreted as analytical hypotheses subject to subsequent testing using panel data, structural models or configuration methods (e.g. fsQCA). Fourth, proxy measures for ESG integration are methodologically heterogeneous, and some indicators may reflect declaratives rather than performance effectiveness (Eccles & Strohle, 2018). Finally, a significant part of AI innovations develops in transnational corporate ecosystems, which limits the ability of nationally oriented indices to capture the full dynamics of value, data control and platforms.

Despite these limitations, the methodological approach offers a conceptually coherent and empirically sound framework for structuring the interrelationships between AI integration, institutional capacity, and sustainability orientation. In this way, the section serves a dual function: (i) systematizes the fragmented literature and indicator base; and (ii) formulates clearly defined dependencies and typologies that can be subject to future quantitative verification.

4 AI as a mediator of structural transformation

In this article, artificial intelligence is viewed as a mediator of structural transformation, whose impact on economic dynamics is indirect and operates through the restructuring of production factors, institutional incentives, and innovation ecosystems. Drawing on the logic of technological revolutions (Perez, 2002), this impact remains conditional on institutional alignment and strategic coordination. Accordingly, AI can function as a catalyst for a sustainable digital leap only in the presence of three systemic prerequisites:

- institutional capacity and strategic management;

- adequate human capital;
- access to a stable digital infrastructure.

The absence of any of these prerequisites transforms AI from a tool of modernization into a mechanism of dependency.

4.1 Institutional capacity and strategic management

Institutional capacity refers to the ability of a state to formulate, coordinate and implement long-term strategies that combine regulatory frameworks, investment incentives and industrial policy. In the AI context, this capacity becomes critical due to the horizontal nature of AI, that cuts across sectors and governance domains. As North (1990) argues, institutions fundamentally shape the structure of the economy. In an AI environment, this extends to the data governance, algorithmic accountability, competition and protection of rights. The importance of transparency and disclosure as pillars of governance has been extensively discussed in the corporate governance literature, seen as preconditions for long-term trust and sustainable performance (Zhelev, 2020). A lack of regulatory predictability reduces investment activity, while excessive or inconsistent regulation can hinder innovation (OECD, 2019) (Ebers et al., 2021).

Industrial policy plays a key role in technological catch-up (Rodrik, 2011), which outlines the need for strategic investments in research infrastructure, incentives for innovation clusters and targeted missions that guide development towards societal priorities (Mazzucato, 2013). The “triple helix” model (Etzkowitz & Leydesdorff, 2000) shows that sustainable innovations emerge from synchronized interaction between state, business and academia. Leading AI ecosystems demonstrate precisely such institutional integration (Stanford Institute for Human-Centered Artificial Intelligence (HAI), 2024) (World Economic Forum, 2024). In the absence of coordination, developing economies remain dependent on external platforms and technologies.

From an analytical perspective, institutional capacity functions as a transmission mechanism that determines whether AI contributes to structural transformation or reinforces existing constraints. Under conditions of institutional alignment, AI

supports structural modernization; in fragmented regulatory environments, it tends to reproduce dependency and limit endogenous value creation.

4.2 Human capital and digital skills

Human capital determines the ability of an economy to absorb and adapt general-purpose technologies (Aghion, Antonin, & Bunel, 2023). In an AI environment, this extends beyond advanced technical expertise (e.g. machine learning, data analytics) to include managerial, regulatory, and ethical competencies necessary for integrating AI into organizational and institutional processes (OECD, 2019) (UNESCO, 2021). Economies with a high level of digital skills realize higher returns on investments in digital transformation (OECD, 2023). By contrast, limited human capital constrains endogenous innovation and increases reliance on imported technological solutions, thereby reducing value creation capacity. However, AI transformation raises the risk of polarization in the labour market. Research by Acemoglu and Restrepo (2018) and Autor (2015) shows that automation can displace routine activities and increase inequalities. In developing economies, this process can deepen structural weaknesses in the absence of retraining and social adaptation programs (World Bank, 2021).

From an analytical perspective, the impact of AI on productivity and innovation is conditional on the alignment between technology strategy and human capital development. When supported by education and social adaptation policies, AI enhances innovation capacity; in their absence, it reinforces labour market segmentation and structural vulnerability.

4.3 Infrastructure and technological autonomy

AI operates on three resources: data, algorithms and computing power. Digital infrastructure is therefore not just a technical prerequisite, but a strategic component of economic autonomy. The World Development Report: Data for Better Lives (World Bank, 2021) defines data as a strategic resource whose management requires institutional mechanisms for protection and transparency. OECD (2023) emphasizes that high digital intensity of companies is linked to robust broadband infrastructure and access to cloud services.

The global concentration of cloud and AI platforms in a limited number of corporations is creating new forms of dependency (UNCTAD, 2023). For economies without their own capacity to manage data and computing resources, this means reduced control over strategic assets and limited innovation autonomy. Historically, industrial modernization required the construction of physical infrastructure; in the AI era, a similar role is taken on by digital ecosystems and data.

The conditional logic states: When infrastructure is supported by institutional governance and strategic vision, AI reinforces economic complexity; when dependent on external platforms, it deepens structural vulnerability.

4.4 Strategic scenarios for emerging economies

The accumulated theoretical and methodological analysis allows the formulation of an analytical model of the strategic paths facing emerging economies in the era of AI. Within this framework, AI is treated a conditional technological factor, whose impact on economic structure depends on the configuration of institutional capacity and sustainability integration. Accordingly, two ideal-typical outcomes can be distinguished (Hall & Soskice, 2001):

- consolidation of digital dependence;
- sustainable structural transformation.

The distinction between these outcomes does not derive from the intensity of the technological adoption, but from the alignment between three systemic dimensions: a) AI readiness and integration (**A**); b) institutional capacity and strategic coordination (**I**); c) sustainability integration / ESG orientation (**S**).

Scenario I: Dependency configuration: digitalization without structural leap

This scenario assumes an increasing level of AI deployment, but with limited institutional capacity and weak strategic integration. Technological progress is largely based on externally developed platforms, cloud services and algorithmic solutions controlled by global technology ecosystems. As UNCTAD (2023) highlights, the concentration of AI infrastructure and computing capacity creates an asymmetric

environment in which developing economies remain predominantly users rather than creators of innovation.

In this scenario, AI is primarily applied to the automation and optimization of existing processes, without significant changes in the production structure. The added value resulting from the development of models, data and intellectual property is accumulated outside the national economy. According to Perez (2002), technological adoption without institutional alignment leads to partial modernization, without structural transformation, a dynamic consistent with limited economic complexity (Hausmann & Hidalgo, 2011).

In this configuration, ESG policies tend to function in a formal or compliance-driven manner, without integration into industrial strategy. As a result, digitalization can deepen existing dependencies, transforming them from industrial to algorithmic. This creates a state of dependency-driven digitalization, in which technological dynamics do not fundamentally change the position of the economy in the global hierarchy of value.

Scenario II: Synergy Configuration: AI as a Mediator of Sustainable Structural Transformation

The second scenario assumes a strategic alignment between AI integration, institutional capacity, and sustainability orientation. Here, AI functions as an enabling infrastructure for diversification and increased economic complexity.

Sustainable innovation growth, according to Aghion et al. (2023), requires a combination of technological dynamism and institutional stability. The institutions involved (North, 1990) (Acemoglu & Robinson, 2012) provide predictability, protection of rights and incentives for long-term investment. When AI integration is supported by a mission-oriented industrial policy (Mazzucato, 2013) and coordination between the state, business and academia, technological potential is transformed into a systemic competitive advantage. In this configuration, ESG orientation functions as a strategic filter and corrective. Rather than being an external normative tool, it directs investments towards sectors with high social returns – smart energy systems, digital healthcare, sustainable transport. According to the logic of shared value (Porter & Kramer, 2018), economic efficiency and social sustainability reinforce each other. Evidence from EU-based listed companies

suggests that sustainability regulation affects not only compliance structures but also the internal configuration of business models, including supplier relationships, value chain activities and capital allocation patterns (Boeva, 2024).

Formalizing the strategic configuration

To make the proposed model analytically operational, the interrelationships between the main constructs can be represented through a structural specification. In the context, ***A*** denotes the **degree of AI readiness and integration**, ***I*** – **institutional capacity**, ***S*** – **sustainable (ESG) integration**, ***D*** – **digital competitiveness**, and ***Y*** – **sustainable structural transformation**. Within the model, AI affects transformation indirectly through institutional mediation and competitiveness dynamics. This can be formalized as follows (equation 1):

$$D = \beta_0 + \beta_1 A + \beta_2 (A * I) + \varepsilon \quad (1)$$

In this case, the effect of AI on digital competitiveness is dependent on institutional capacity. At low levels of *I*, the impact of *A* on *D* remains limited or unstable – in line with the technological complementarity thesis (Brynjolfsson, Rock, & Syverson, 2021), according to which technologies of general application require accompanying institutional and organizational changes.

In turn, sustainable structural transformation depends on the interaction between digital competitiveness and the degree of sustainable integration (equation 2):

$$Y = \delta_0 + \delta_1 D + \delta_2 S + \delta_3 (D * S) + \varepsilon \quad (2)$$

A positive coefficient δ_3 means that **digital competitiveness becomes a sustainable structural outcome only in the presence of a strategically integrated ESG orientation**. Thus, the impact of AI is both mediated by institutional capacity and conditional on the sustainability framework.

Conceptually, strategic pathways can be further described through threshold logic. Sustainable transformation is possible with both high values of institutional capacity ($I \geq \tau_I$) and integration of sustainable development principles ($S \geq \tau_S$), with a sufficient level of AI readiness. If any of these conditions is not met, technological

integration remains partial and may reproduce structural constraints. This leads to an analytical matrix of configurations (Table 1):

Table 1: Matrix of configurations between level of institutional capacity and level of ESG integration

Institutional capacity	ESG integration	Expected effect of AI
Low	Low	Digital dependency
High	Low	Modernization without sustainability
Low	High	Regulatory ambition without capacity
High	High	Sustainable structural transformation

Source: Author’s elaboration

Thus, the proposed model represents an analytical framework of mediated and contingent dependencies in AI-mediated transformation. Its theoretical contribution consists in demonstrating a double conditionality: first, institutional, since AI generates systemic competitiveness only with sufficient institutional capacity; and second, along the lines of sustainability, since digital competitiveness becomes a sustainable structural transformation only with an integrated ESG orientation. The model demonstrates that AI’s impact is not determined by access alone, but by the configuration of institutional and sustainability conditions.

5 Discussion

The proposed model (AI readiness → digital competitiveness → sustainable structural transformation, given institutional stability and resilience) allows for a transition from a theoretical framework to specific political and economic conclusions. The key implication is that AI should not be treated as an autonomous technological goal, but as a component of a broader strategy for institutional alignment and structural renewal. The difference between technological adaptation and structural transformation is manifested in the ability of the state to transform technological potential into systemic competitiveness, social security and long-term sustainability.

First, the model emphasizes the role of institutional architecture as a transmission mechanism of technological effect. Institutional capacity is an active mediator through which AI investments are transformed into competitive advantage (North, 1990). Under conditions of fragmented coordination or limited administrative

capacity, technological initiatives remain isolated and short-term. In the AI context, this includes building coherent frameworks for data governance, algorithmic accountability and competition policy towards digital platforms (OECD, 2019) (UNESCO, 2021). The transition required is from deployment incentives to institutionalized coordination and regulatory capacity. Only with such institutional consolidation can AI policy go beyond pilot projects and become an instrument of structural modernization.

Second, the integration of sustainability should be seen as a guiding principle, not a secondary element of digital strategy. General-purpose technologies can accelerate productivity, but without social and environmental mechanisms, the effect is often asymmetric and politically unstable (Aghion, Antonin, & Bunel, 2023). The literature outlines risks of labour polarization (Autor, 2015) (Acemoglu & Restrepo, 2018), regional concentration of digital benefits (OECD, 2025), increasing energy intensity in the absence of green infrastructure, and concentration of market power (UNCTAD, 2023). The implication is a shift toward ESG-by-design, embedding sustainability criteria directly into strategic planning and investment decisions. In this sense, ESG does not function as a moral corrective, but as a strategic filter that ensures the public legitimacy and long-term stability of the digital transformation.

Third, the logic of the model assumes an active but not directive role of the state as the architect of the market. When the outcome depends on coordination and institutional transmission, the public sector inevitably participates in building the innovation ecosystem, sharing risk and creating conditions for market formation (Rodrik, 2011) (Mazzucato, 2013). For developing economies, this means choosing priority sectors (niches) with the potential to increase economic efficiency (Hausmann & Hidalgo, 2011), using public procurement as a tool to create demand for ethical and reliable AI solutions, investing in data and computing infrastructure, and promoting public-private partnerships. The objective is not isolation, but strategic positioning within global value networks.

Fourth, social transition is an integral part of a sustainable AI strategy. Labor market restructuring increases the risk of displacement and segmentation, particularly in economies with high shares of routine employment. Without adaptive social mechanisms, declining trust and rising instability can undermine digital transformation (World Bank, 2021). Therefore, mass retraining programs,

institutionalized lifelong learning, adapted social protection systems, and regional policies for digital convergence are not secondary measures, but conditions for sustainability. Social policy in this context is not reactive, but a component of strategic planning.

Finally, geo-economic dimensions complement the model, as the global AI ecosystem is concentrated in terms of patents, platforms and computing resources (Stanford Institute for Human-Centered Artificial Intelligence (HAI), 2024), raising the question of control over critical dependencies. Technological sovereignty does not mean isolation, but the ability to strategically choose and manage interdependencies – through diversification of partnerships, regional coordination and a minimum national capacity to manage critical digital infrastructure.

This research shows that emerging economies face a strategic bifurcation between digitalization that reproduces dependency and AI-mediated sustainable structural transformation. The determining factor is institutional and strategic, not technological: the quality of governance transmission and the degree of ESG integration determine whether AI will remain a tool for partial optimization or function as a catalyst for sustainable structural renewal. In this sense, the sustainable digital leap is not a technological phenomenon, but a managerial choice that requires coordination between industrial policy, education, social adaptation, regulation and geo-economic positioning.

6 Conclusion

This paper focuses on the strategic dilemma of whether accelerated AI transformation will deepen the existing digital lag of developing economies or can become a mechanism for sustainable structural leapfrogging. The main conclusion is that AI is neither an autonomous engine of catch-up nor an inevitable source of dependency, but a conditional technological accelerator.

The theoretical contribution of the article lies in the **development and formalization of a mediation model** that links AI readiness, institutional capacity, and ESG integration with digital competitiveness and structural transformation. The model demonstrates that **AI effects are non-linear and mediated by institutional capacity**. A sustainable **digital leap emerges only under a specific configuration**

of technological readiness, institutional quality and ESG integration. The study **contributes by integrating** these dimensions into a unified analytical framework.

The proposed scenario typology (digital dependency vs. sustainable structural leap) can be used as a conceptual tool for comparative analysis of economies in the global digital system. It highlights that fragmented digitalization based on external technologies has limited transformative capacity. Conversely, an integrated industrial policy, supported by investments in human capital, computing infrastructure and institutional strengthening, increases the likelihood that AI will become a source of increased economic complexity and long-term sustainability.

The practical implications are consistent with this logic. AI strategies in emerging economies should not be isolated technological documents, but part of broader institutional and industrial reform. Policies should simultaneously strengthen data governance, modernize education systems, provide social adaptation mechanisms, and integrate ESG criteria into the investment planning process. In this context, technological sovereignty does not mean isolation, but the ability to make strategic choices, manage dependencies, and control critical resources of the digital economy. The study also outlines directions for future empirical validation of the model. These include panel models, mediation and interaction analysis, and configurational approaches such as fsQCA. Ultimately, the dilemma facing emerging economies in the AI era is not a question of technological access, but of managerial maturity. Digital lag and sustainable structural leap represent alternative outcomes shaped by institutional configurations rather than predetermined trajectories.

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UNDERSTANDING ANTICONSUMPTION IN TOURISM SERVICES: A QUALITATIVE STUDY OF YOUNG SLOVENIAN TRAVELERS

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This research aims to explore how anticonsumption manifests in tourism, specifically among young Slovenian consumers. It addresses a gap in the literature, which often focuses on promoting sustainable products while overlooking the reasons behind anticonsumption in the tourism and service sectors (Garima et al., 2024). The study highlights the disparity between sustainable attitudes and actual vacation behaviours (Nikolić et al., 2021). Using a qualitative approach, the methodology includes conducting a focus group with young adults to identify motivations for and against anticonsumption in tourism (Liu-Lastres et al., 2025). The research will also examine psychological mechanisms like moral disengagement (Pizzetti et al., 2024) and guilt (Mkono & Hughes, 2020), as well as cultural factors relevant to Slovenia (Krsnik & Erjavec, 2024). The collected data will undergo content analysis and coding to provide deeper insights. Expected findings include key motives influencing anticonsumption behaviour and why sustainable practices often fall short in vacation settings. This research aims to clarify how participants rationalize their decisions. The findings will help marketing professionals develop credible, sustainable strategies and adapt offerings that promote responsible vacation behaviours.

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1 Introduction

In modern society, consumption is a key driver of economic growth but also a significant source of environmental pressure. The widespread culture of consumerism promotes excessive consumption, depletes natural resources, deepens social inequalities, and poses risks to human well-being (Garima et al., 2025). Unsustainable consumption patterns are therefore recognized as one of the key drivers of environmental change, and the transition to more moderate forms of consumption is becoming central to sustainable development (Kropfeld et al., 2018).

This problem is particularly pronounced in tourism, which is one of the most consumption-intensive activities, intricately linked to materialism, income growth, and broader consumer culture (Hall, 2011). Although the discourse on sustainable tourism has intensified in recent decades, many sustainable practices often do not reduce overall consumption levels, but rather reproduce them in a green form. This approach can serve as a moral compromise, allowing individuals to maintain their travel habits without thoroughly reflecting on their necessity, frequency, or impact (Gričar et al., 2025). This raises the question of whether merely promoting sustainable alternatives is adequate to reduce the environmental impact of tourism.

In this context, anticonsumption is presented as an alternative research framework. It refers to the conscious, voluntary decision to exclude specific products or services from consumption, or to reduce or avoid consumption altogether (Garima et al., 2025; Garcia-de-Frutos et al., 2018). A key characteristic of anticonsumption is its voluntary nature and its connection to personal identity, which sets it apart from behaviours that reduce consumption due to external constraints (García-de-Frutos et al., 2018). The typology of Iyer and Muncy (2009) further distinguishes anticonsumption according to object (general reduction or reduction of a specific product, brand, or activity) and purpose (individual or social motives).

Despite growing interest in anticonsumption, significant knowledge gaps remain. Many studies primarily focus on products, while the service sector, especially tourism, remains under-researched (Lee, 2022; Makri et al., 2020; Garima et al., 2025). Additionally, much of the existing research has been conducted predominantly in Western countries, thereby largely overlooking the role of cultural differences (Garima et al., 2025). Furthermore, there is an apparent discrepancy

between attitudes and behaviour in tourism: individuals who adopt sustainable practices at home often fail to extend them to the vacation context (Barr et al., 2010; Cohen et al., 2011; Pizzetti et al., 2024), where norms are relativized or even suspended (Liu-Lastres et al., 2025).

Individuals with a strongly positive attitude toward the environment and a high level of environmental concern believe that sustainable practices help reduce their environmental footprint and are aware that such behaviour requires personal sacrifice. However, this logic is often not upheld in the context of tourism, suggesting that tourism operates as a distinct space where sustainability norms are relaxed (Barr & Prillwitz, 2012). These findings suggest that tourism creates a unique moral environment in which people may temporarily redefine or abandon their everyday norms. Understanding this phenomenon, therefore, requires an in-depth analysis of the psychological mechanisms that enable such relativization of sustainable values and explain why sustainable attitudes do not necessarily translate into actual behaviour.

Young people are a particularly relevant group in this regard. Generation Y will make up the largest share of tourists in the future (Liu-Lastres et al., 2025). At the same time, it is deeply embedded in a culture of experiential and often conspicuous consumption. Short flights and city breaks can function as status symbols and a form of conspicuous consumption (Barr et al., 2010; Seegebarth et al., 2024; Cohen et al., 2011). At the same time, research indicates a growing trend of conspicuous anticonsumption, in which people intentionally avoid certain practices to express their identity (Sørensen & Hjalager, 2021; Karakus & Kalay, 2017).

To understand this phenomenon, it is essential to consider psychological factors such as moral disengagement, which allows individuals to justify unsustainable decisions and reduce internal conflict (Bandura, 1996; McCormack & Chowdhury, 2024), and holiday mindset, which frames vacations as a deserved exception to the usual moral expectations of everyday life (Barr et al., 2010; Pizzetti et al., 2024). At the same time, moral emotions such as guilt and regret also play a key role, as they can encourage consumption renunciation and the restriction of unsustainable practices (Lee, 2022; Culiberg et al., 2023; Ram et al., 2013).

An additional dimension is represented by cultural context. Cultural values, such as Hofstede's dimension of indulgence versus restraint (Hofstede, 2011), influence how people view pleasure, leisure, and self-control and can moderate the relationship between psychological factors and individual behaviour (Garima et al., 2025). The conflict between the hedonistic pursuit of pleasure and restrictive sustainability norms is particularly pronounced in tourism (Ram et al., 2013; Seegebarth et al., 2024).

Slovenia represents a particularly relevant research context for examining anticonsumption in tourism. As a small European country with a growing emphasis on sustainable tourism development, it offers a setting in which environmental awareness coexists with increasing travel accessibility and consumption intensity. However, little is known about how anticonsumption is interpreted and enacted within this context, especially among younger generations. It remains unclear how anticonsumption is formed and expressed in tourism, how individuals justify selective restraint in a hedonically oriented domain, and how psychological mechanisms and cultural orientations shape the transfer (or suspension) of sustainable practices during holidays.

This study addresses these gaps by exploring how young Slovenian travellers understand and negotiate reductions in consumption in tourism services. By integrating psychological, symbolic, and contextual perspectives, the study contributes to a more nuanced understanding of why sustainable attitudes do not necessarily translate into reduced tourism consumption in experiential service settings.

Given the sparse prior research on anticonsumption in tourism services, this study takes an exploratory qualitative approach. It contributes to the literature in three significant ways. Firstly, it broadens the scope of anticonsumption research into the underexplored area of tourism services, demonstrating that anticonsumption manifests as selective, negotiated restraint rather than a total reduction in consumption. Secondly, it integrates psychological factors (such as moral disengagement and feelings of guilt), symbolic aspects (such as identity signalling), and contextual elements (including tourism as an exceptional domain) to explain the gap between attitudes and behaviours in tourism consumption. Lastly, the study

provides empirical insights from a European perspective, enhancing cultural understanding of anticonsumption in tourism, which has thus far been limited. Based on the identified theoretical gaps, the following research questions guide the analysis:

RQ1: How do young Slovenian travellers understand anticonsumption in the context of tourism services?

RQ2: Which psychological mechanisms (e.g., moral disengagement, guilt) shape the relationship between sustainable attitudes and actual tourism behaviours?

RQ3: How do symbolic factors, particularly conspicuous consumption and identity signalling, influence the (non-)adoption of anticonsumption in tourism?

RQ4: Under what conditions are young travellers willing to reduce the intensity or frequency of tourism consumption?

2 Literature review

2.1 Anticonsumption

Anticonsumption refers to the intentional and voluntary act of reducing, restricting, or rejecting consumption. It signifies a conscious shift away from prevailing consumption-oriented lifestyles. Rather than just avoiding consumption, anticonsumption involves making active behavioural choices guided by environmental, ethical, or personal values (Peng et al., 2024). Similarly, Kropfeld et al. (2018) define anticonsumption as a lifestyle characterized by the voluntary reduction of the acquisition, use, and abandonment of goods and services.

Researchers emphasize that anticonsumption can occur at various stages of the consumption process. It can include refusing to buy, such as boycotting or avoiding certain goods, as well as using less and being responsible when giving up ownership, such as giving away, selling, lending, or returning items to circulation (Guillard, 2018). In this sense, anticonsumption reflects a broader transformation of consumer norms, in which individuals reevaluate their needs, minimize their reliance on physical possessions, and adopt more moderate, thoughtful consumption patterns

(Peng et al., 2024). These practices range from everyday behaviours, like cutting back on purchases and extending the lifespan of products through repair and reuse. They can also encompass more dedicated lifestyles, such as voluntary simplicity, minimalism, political activism, or engagement in alternative consumption models (Cherrier et al., 2010; Guillard, 2018). Anticonsumption can therefore be understood as a multidimensional and continuous phenomenon that varies among individuals in terms of intensity, motives, and the meaning they attribute to reducing consumption (Guillard, 2018; Ines & Moreira, 2025).

Iyer and Muncy (2009) offer an important conceptual contribution by distinguishing between anticonsumption based on object and on motive. From an object perspective, individuals may either reject consumption altogether or choose to give up certain products, brands, or activities. From a motivational standpoint, anticonsumption can result from personal goals, such as reducing stress and embracing a simpler lifestyle, as well as broader concerns about social and environmental issues. Research indicates that environmental motives do not solely drive anticonsumption; instead, they are influenced by a combination of personal benefits (e.g., saving money, a sense of autonomy, well-being, and identity expression) alongside broader ethical and social goals (Cherrier et al., 2010; Ziesemer et al., 2021). Anticonsumption is therefore a complex phenomenon that cannot be explained solely by environmental or economic factors.

Unlike sustainable consumption, which often involves replacing conventional products with more environmentally friendly alternatives, anticonsumption emphasizes reducing overall consumption. The higher costs associated with sustainable alternatives often create financial barriers that hinder their wider adoption, even when consumers have positive intentions (Ziesemer et al., 2021). Anticonsumption overcomes this limitation by focusing on reducing consumption rather than merely replacing products. This distinction is crucial, as reducing overall consumption can yield a greater reduction in environmental impact than simply switching to sustainable alternatives while maintaining the same level of consumption (Peng et al., 2024; Kunar et al., 2020).

Research further shows that sustainable consumption does not always lead to long-term behavioural change, as individuals often continue with unsustainable practices despite their positive environmental attitudes (Black & Cherrier, 2010). In contrast,

anticonsumption offers a more comprehensive approach to reducing environmental effects by actively curbing consumption rates (Kropfeld et al., 2018). Empirical findings indicate that anticonsumption is negatively associated with tendencies toward overconsumption, including impulse buying, prominent levels of material possessions, and financial debt (Seegebarth et al., 2016). Furthermore, an anticonsumerist lifestyle is more effective at reducing environmental impact than merely expressing environmental concern, underscoring that limiting consumption is a key mechanism for achieving sustainability goals (Kropfeld et al., 2018).

In the context of tourism, anticonsumption is particularly relevant, as tourism is a highly consumption-intensive activity. Despite efforts to promote sustainable tourism, research consistently finds a gap between pro-environmental attitudes and actual tourist behaviour (Holmes et al., 2021). Anticonsumption offers a unique perspective on this issue, highlighting that sustainable values can be expressed through reducing or abandoning consumption rather than solely opting for sustainable products (Black & Cherrier, 2010).

Similarly, concepts like slow tourism embody related ideas, emphasizing less frequent travel, longer stays, and less intensive consumption habits. Nevertheless, these concepts have not gained widespread popularity because they often conflict with prevailing social norms that associate tourism with intensive consumption and status signalling (Chauhan, 2024). However, there are crucial differences between them. While slow tourism can still be seen as a form of consumption involving travel activities, anticonsumption emphasizes the deliberate reduction or abandonment of consumption as such. Anticonsumption, therefore, does not simply mean choosing a different form of consumption, but can also involve consciously limiting the scope or frequency of travel. This further emphasizes its importance as a relevant theoretical framework for understanding consumption in a tourism context.

2.2 Conspicuous Consumption

Conspicuous consumption is the tendency for individuals to demonstrate their social status, identity, or personal values through the purchase and use of goods or services that are easily visible to others (Bronner & de Hoog, 2018). Such consumption goes beyond mere product functionality, as it primarily serves symbolic purposes, such as showcasing prestige, accomplishments, affiliation, or individual identity. People

often engage in consumption as a means of social signalling, differentiation, and self-presentation, driven by a desire for recognition, admiration, and social acceptance. Thus, conspicuous consumption is closely tied to the pleasure-seeking and symbolic dimensions of consumer behaviour (Effler et al., 2022).

Recent consumer trends indicate a shift from material to experiential consumption, with more people choosing to invest in experiences, such as travel, that allow them to convey their identity and lifestyle publicly. Although consumption has traditionally been associated with material goods, today it increasingly manifests itself through experiences, which, due to their social visibility, are becoming an important means of symbolic differentiation. This process is further reinforced by social networks, which make it easy to share otherwise fleeting experiences and increase their symbolic value. An individual's identity is thus no longer expressed solely through ownership, but also through the choice of activities, destinations, and modes of travel (Bronner & de Hoog, 2019).

Tourism, therefore, represents a particularly prominent area of conspicuous consumption. Tourist destinations frequently serve as indicators of status, as traveling to specific locations allows individuals to express their prestige, uniqueness, or social standing (Šagovnović & Kovačić, 2024). Holidays are not just a way to relax, but also a means of shaping and expressing one's identity. By choosing a destination, accommodation, activities, and transportation method, individuals actively shape and project their social status (Bronner & de Hoog, 2019). Given that status relies on uniqueness and novelty, tourism fosters an ongoing quest for new and unique experiences that facilitate further symbolic differentiation (Šagovnović & Kovačić, 2024).

Social networks are crucial in this context, increasing the visibility of travel experiences and strengthening social pressure to participate in such behaviours. Young travellers are susceptible to social comparison and the influence of reference groups, often viewing travel as a key avenue for social recognition and identity affirmation (Liu & Huang, 2019). Visually appealing social media content further enhances the symbolic value of travel and promotes conspicuous consumption within the tourism sphere (Wang et al., 2025). Influencers often emphasize the aesthetic and symbolic aspects of travel, while sustainability aspects remain less prominent (Asri et al., 2024). These dynamics contribute to increased social

pressures, the fear of missing out (FOMO), and the normalization of frequent travel as a desirable social activity (Seyfi et al., 2025).

However, conspicuous consumption can also be expressed through sustainable practices. The concept of going green to be seen suggests that individuals sometimes make sustainable choices to signal socially desirable values and enhance their reputation (Stoll-Kleemann & O'Riordan, 2020). Similarly, tourists value more sustainable elements of tourist destinations that are visible, aesthetically appealing, and symbolically recognizable, indicating that they have an important symbolic function in addition to their environmental function (Aydin & Alvarez, 2020). Sustainable practices are therefore not always motivated exclusively by environmental reasons but can also serve as a means of social signalling.

It is therefore important to note that conspicuous consumption and anticonsumption are not necessarily complete opposites. Both can serve to express identity and symbolically differentiate. Individuals can demonstrate their moral principles or social status by rejecting consumption, as others do through conspicuous consumption (Effler et al., 2022). Non-conspicuous consumption, therefore, does not necessarily imply reduced consumption but may reflect a transition towards more subtle ways of symbolically distinguishing oneself (Wu et al., 2017).

In the realm of tourism, conspicuous consumption further reinforces consumer behaviour, as travel is frequently seen as a reward, an escape from everyday life, and a symbol of personal success (Barr & Prillwitz, 2012). This mindset makes it difficult to accept practices aimed at reducing consumption, highlighting the tension between tourism's symbolic values and the pursuit of sustainable behaviour. Understanding conspicuous consumption is therefore key to explaining why individuals often continue to engage in consumption-intensive tourism practices despite their sustainable values.

2.3 Moral disengagement

Moral disengagement is a psychological defence mechanism that allows individuals to justify behaviour that deviates from their moral standards and to reduce feelings of guilt and internal conflict arising from the inconsistency between their values and

their actual behaviour (Bandura, 1996; Sharma & Paco, 2021). When individuals act contrary to their moral beliefs, they experience psychological discomfort associated with cognitive dissonance and a threatened moral self-image (Sharma & Lal, 2020). To preserve a favourable self-image, they employ mechanisms of moral disengagement that allow them to reinterpret or rationalize their actions (Leviston & Walker, 2021).

Bandura (1996) explains that moral disengagement is a process of temporarily deactivating internal moral brakes, in which individuals cognitively transform the situation so that their behaviour becomes morally acceptable. This process involves several mechanisms. First, moral justification, in which individuals present their actions as necessary, beneficial, or justified, often using euphemisms or comparisons with more harmful behaviours. Second, diffusion or transfer of responsibility, which involves attributing responsibility to external influences, other people, social norms, or institutional entities, resulting in a diminished sense of personal accountability (Leviston & Walker, 2021; Ines & Moreira, 2025). Third, individuals may downplay or deny the adverse outcomes of their actions, thereby minimizing the perceived harm or questioning its significance. Fourth, they might redirect blame to the victim or devalue those affected, thereby lessening empathy and facilitating the justification of harmful behaviour (Bandura, 1996). Another key mechanism is moral licensing, in which individuals justify unsustainable decisions by referencing prior pro-environmental actions (Nielsen et al., 2024). Furthermore, people often justify unsustainable behaviour by pointing to external factors such as time limits, costs, convenience, or the absence of alternatives, which diminishes their sense of personal responsibility (Seyfi et al., 2025).

Moral disengagement is a situational and motivated process that is more likely to be activated when an unsustainable choice is attractive to the individual or brings personal benefits. The greater the perceived benefit, the greater the likelihood of rationalization (Killian & Mann, 2020). As a result, moral disengagement increases the likelihood of choosing unsustainable alternatives and reduces the willingness to choose sustainable options, thereby widening the gap between attitudes and behaviour (Wu et al., 2021).

In the context of tourism, moral disengagement is particularly pronounced. Tourists often express concern for the environment, yet experience tension between their environmental values and behaviour on vacation (Juvan & Dolnicar, 2014). Individuals often address this dilemma by rationalization, such as viewing vacations as a legitimate exception to daily standards or by justifying air travel based on time constraints and comfort (Mkono & Hughes, 2020; Barr & Prillwitz, 2012; Nielsen et al., 2024). The context of tourism further encourages moral disengagement, as anonymity and a break from daily routines can diminish self-regulation (Wu et al., 2025). Vacations are thus frequently perceived as opportunities to temporarily relax moral standards (Mkono & Hughes, 2020).

Empirical research confirms that moral disengagement acts as an important inhibitory mechanism for sustainable behaviour. While moral obligation encourages pro-environmental behaviour, moral distance allows for the rationalization of unsustainable decisions without guilt, with both mechanisms having a comparably strong influence on behavioural intentions (Wu et al., 2021). Moral distance thus represents a key psychological mechanism that enables the maintenance of unsustainable practices despite the presence of sustainable values in the tourism context.

In the context of tourist consumption, anticonsumption and moral disengagement are linked through tourists' management of moral conflict. Anticonsumption reflects ethically motivated efforts to reduce, avoid, or reject forms of tourism consumption perceived as socially or environmentally harmful. Moral disengagement, in contrast, enables tourists to justify continued participation in problematic tourism practices by minimizing perceived impacts, diffusing responsibility among tourists and providers, or normalizing such behaviours. When moral disengagement is limited or resisted, tourists may turn to anticonsumption as a means of restoring moral alignment between their values and travel-related behaviours. Thus, anticonsumption and moral disengagement represent contrasting strategies for resolving moral tension in tourist consumption and should therefore be negatively related.

2.4 Guilt

Eco-guilt refers to the negative moral feelings that individuals experience when they are aware of or concerned about their own environmentally harmful behaviour (Mkono & Hughes, 2020). It stems from a perceived moral obligation to oneself, society, or nature and reflects a personal commitment to sustainable values. Key to its emergence is perceived knowledge of sustainable options for action and the belief that individuals can contribute to reducing environmental problems through their behaviour. When individuals feel powerless or constrained by their circumstances, their sense of eco-guilt diminishes or disappears (Nielsen et al., 2024).

Although eco-guilt serves as a moral response, it does not automatically result in behavioural change. Instead, it often triggers rationalization processes that allow individuals to neutralize negative feelings without altering their behaviour. Eco-guilt is highly context-dependent and fleeting, typically arising during a specific decision-making moment and serving as an internal reminder or a source of cognitive conflict rather than a stable indicator of behavioural change. Those with a strong environmental awareness tend to experience eco-guilt more often. However, they also have better strategies to cope with it, for example, through suppression, reinterpretation, or engaging in compensatory behaviours (Nielsen et al., 2024).

Nevertheless, eco-guilt has significant potential to encourage sustainable behaviour, especially when individuals acknowledge their personal responsibility for their actions. In such cases, it acts as a moral regulator, encouraging behaviour consistent with one's values (Nielsen et al., 2024). Negative moral emotions, like guilt and shame, can drive individuals to make more environmentally responsible decisions. However, they can also trigger defence mechanisms, such as moral disengagement, which rationalize unsustainable behaviour (Stoll-Kleemann & O'Riordan, 2020). For instance, tourism research indicates that feelings of guilt can lead individuals to avoid certain consumption types, such as boycotting environmentally harmful tourism practices, demonstrating its potential as a self-regulation mechanism (Park & Jang, 2024).

The role of eco-guilt is particularly relevant among young consumers, who are both highly environmentally conscious and intensely involved in the symbolic and status dimensions of consumption, especially in the context of tourism. This duality can

increase internal conflict between values and behaviour, thereby activating eco-guilt. However, due to significant exposure to social norms and the pressure for visibility, young people may often resort to rationalization or moral disengagement strategies, thereby easing emotional discomfort without changing their behaviour. The dynamics between eco-guilt, social pressure, and identity formation are therefore key to understanding anticonsumerist decisions in this generational group.

In the context of tourism, eco-guilt and anticonsumption are intricately connected through emotional responses to perceived environmental harm. Eco-guilt arises when tourists recognize the negative environmental impacts of their travel-related consumption, such as carbon emissions, overuse of natural resources, or contribution to overtourism. This feeling of guilt can motivate anticonsumption by encouraging tourists to reduce, avoid, or selectively reject certain tourism activities to alleviate emotional discomfort and restore a sense of moral and environmental responsibility (Culiberg et al., 2023).

2.5 Cultural Factors

Cultural values represent an important framework that shapes individuals' perceptions, attitudes, and behavioural decisions, including consumer and tourist behaviour (Kuanr et al., 2021). Hofstede (2011) defines culture as the collective programming of the mind that distinguishes members of one society from another and changes relatively slowly. Cultural values thus function as a deeply rooted system that influences the interpretation of information, the formation of preferences, and the boundaries of acceptable behaviour. Even with globalization, cultural differences tend to remain relatively stable, underscoring the importance of considering them for a better understanding of consumer decisions and the limitations of applying findings directly across countries.

Hofstede's dimension of indulgence versus restraint is particularly relevant to this analysis, as it concerns the extent to which a society allows the gratification of desires related to pleasure, relaxation, and enjoyment. Cultures with a high level of indulgence allow relatively free satisfaction of these desires, reflected in greater appreciation of leisure time, a sense of personal control over life, personal freedom, and the belief that life is meant to be enjoyed. As a result, individuals in such cultural environments show a greater willingness to engage in spontaneous consumption and

to participate more frequently in hedonistic activities such as travel. In contrast, cultures that exhibit higher levels of restraint tend to have more rigid social norms, greater self-regulation, and control over personal desires. These cultures often prioritize values like duty, discipline, and adherence to social expectations. Individuals in these societies are more likely to experience a sense of limited personal control over their life circumstances, attach less importance to leisure time, and may feel more guilt about hedonistic activities such as tourism (Hofstede, 2011; Zhang et al., 2019).

The contrast between indulgence and restraint is crucial to understanding consumption patterns in tourism, which is a distinctly hedonistic activity associated with self-reward, leisure, and symbolic enjoyment. Cultural attitudes regarding the acceptability of enjoyment thus significantly influence how individuals perceive travel and their consumption habits in this context. Empirical research indicates that individuals from cultures characterized by high indulgence place greater emphasis on hedonistic, relaxing, and pleasure-driven tourism experiences, reflecting their stronger focus on satisfaction and personal enjoyment (Meng Ji et al., 2023). These individuals also tend to report higher satisfaction with the tourism experiences (Huang & Crotts, 2019), suggesting that cultural influences shape tourism behaviour (Koc et al., 2017).

Moreover, cultural values play a key role in anticonsumerist behaviour, as they shape how individuals interpret information and decide whether to reduce or eliminate consumption (Kuanr et al., 2021). Given that tourism is strongly associated with enjoyment, status, and hedonism, the indulgence-restraint spectrum can influence individuals' willingness to curtail their consumption. Cultures with a greater emphasis on enjoyment may decrease the motivation to limit tourism consumption, while those with a greater emphasis on self-regulation may encourage more moderate consumption practices.

While cultural dimensions are often used to describe differences between nations, research reveals considerable cultural diversity within countries, driven by factors such as migration, tourism, global media exposure, international commerce, and other aspects of globalization (Heydari et al., 2021). Individuals within the same country do not necessarily share the same values, which justifies researching cultural dimensions at the individual level and allows for a more accurate connection

between cultural values, personal norms, and behavioural decisions (Huang & Crofts, 2019; Heydari et al., 2021).

Despite the established influence of culture on consumer behaviour, the link between the indulgence dimension and sustainable and anticonsumerist behaviours in tourism remains under-researched. Further research is needed to examine how cultural values shape (un)sustainable consumption patterns and moderate the relationship between psychological factors and individual behaviour in a tourism context (He & Filimonau, 2020).

2.6 Gen Y

Generation Y is a crucial demographic for predicting future trends in tourism consumption, as they will constitute the largest share of tourists in the years to come (Liu-Lastres et al., 2025). Their significance is therefore essential for exploring the possibilities of adopting more sustainable travel behaviour.

For millennials (Generation Y), travel is a central part of their life priorities. They travel more frequently than previous generations, represent the largest segment of international tourists, and their influence on the tourism market is growing as their incomes rise. This generation is noted for prioritizing experiences over material possessions, reflected in their preference for authentic experiences, self-directed travel, and support for local businesses. Research also shows that they possess a higher level of environmental awareness and are willing to invest more in sustainable alternatives (Ketter, 2021).

An important aspect of their behaviour is also their attitude toward accommodation. Millennials are key users of the sharing economy and often prefer peer-to-peer accommodation over traditional hotels, mainly because of the perceived authenticity, contact with the local environment, and value for money. They often save on accommodation to spend more on unique experiences. Their travel decisions are closely intertwined with social networks, where they share their experiences intensively, thereby strengthening their own identity and, at the same time, influencing their peers' travel aspirations (Ketter, 2021).

At the same time, young people represent an ambivalent group. On the one hand, they are often seen as potential agents of sustainable change; on the other hand, they are heavily involved in the symbolic and status dimensions of consumption and are exposed to pressure from social networks and reference groups. Travel in the digital space often acts as a means of social signalling and identity formation, which can encourage consumption-intensive forms of tourism. Because of this duality, young people represent a promising but challenging group for promoting anticonsumerist behaviour (Ziesemer et al., 2021).

Empirical research confirms the complexity of their behaviour. The sustainability-oriented segment of tourists is generally younger, more educated, and higher-income, and more consistently transfers its values to the travel context. Nevertheless, there is also a gap between attitudes and actual behaviour in this group, as environmentally conscious individuals often do not behave sustainably during their vacations (Holmes et al., 2021).

A review of existing literature indicates that anticonsumerist behaviour in tourism results from a complex interplay of symbolic, psychological, and cultural influences. The phenomenon of conspicuous consumption creates social pressures to display status and visibility, while conspicuous non-consumption can serve as an alternative way to express identity. The concept of moral disengagement enables individuals to rationalize unsustainable choices, minimizing internal conflict, whereas feelings of guilt can help regulate behaviour and promote consistency between one's values and actions. Additionally, cultural values shape attitudes toward enjoyment, self-discipline, and restraint in consumption, potentially moderating the effects of psychological factors on behavioural decisions. To understand anticonsumption in tourism, it is crucial to adopt an integrative approach that accounts for these interrelated factors, particularly for young Slovenian consumers.

3 Methodology

A qualitative research design was employed to explore how young Slovenian travellers interpret and negotiate anticonsumption in tourism. A focus group method was selected because it enables interactive discussion and facilitates the construction of meanings, allowing researchers to capture shared norms, tensions, and socially negotiated interpretations.

Participants were selected using purposive sampling to ensure relevance to the research topic. The inclusion criteria specified that participants belong to Generation Y and have experience with frequent travel. Eight participants (four females and four males, aged 26–36) took part in a single focus group session lasting approximately 90 minutes. The focus group was conducted in person at the Faculty of Economics and Business, University of Maribor, and moderated by two researchers. With participants' informed consent, the session was audio-recorded and later transcribed word-for-word.

A semi-structured discussion guide was developed based on previous research related to anticonsumption, moral disengagement, holiday mindset, cultural factors, guilt, and conspicuous consumption. Open-ended questions encouraged participants to reflect on their travel habits, motivations, perceived contradictions between values and behaviour, and contextual influences on their decisions. Probing questions were included to foster deeper reflection and clarification. Two academics, one from marketing research and one from consumer behaviour, were presented with research concepts and definitions and reviewed the discussion guide prior to data collection to enhance its clarity and content validity.

Data analysis was conducted using thematic analysis following Braun and Clarke's (2006) six-phase framework. The analysis integrated deductive coding based on relevant theoretical constructs with inductive identification of emerging themes. Initially, the transcripts were read multiple times to become familiar with the data. Then, initial codes were generated across the entire dataset. These codes were organized into broader themes that reflected recurring patterns in participants' thoughts and experiences. Themes were subsequently reviewed, refined, and clearly defined through an iterative analytical process. Themes are presented and described in detail in the Results section.

To enhance the study's credibility and dependability, the researchers engaged in peer debriefing throughout the coding process. The findings section includes rich, verbatim quotations to support transparency and confirmability. All participants provided informed consent before participating in the study. They were informed about the study's purpose, their right to withdraw at any time, and the confidentiality and anonymity of their responses.

This study employs an exploratory qualitative design based on a single focus group, aiming to generate in-depth insights rather than generalizable conclusions. Group interaction influenced individual responses, and recruitment within an academic environment may have resulted in a sustainability-aware sample. The findings should therefore be interpreted as contextually grounded rather than representative of the broader population of Slovenian Generation Y travellers.

4 Results

4.1 General Travel Behaviour

Focus group participants reported frequent travel, typically comprising several shorter trips (e.g., city breaks) and one main vacation, usually seasonal. Shorter trips are often aimed at exploring new destinations, while the main vacation is sometimes linked to a recurring location. There is a distinction between participants who prefer popular and tourist-friendly destinations and those who actively seek out less-traveled locations (off the beaten path).

Most trips are organized independently. Participants cited flexibility, lower costs, the freedom to design their own itineraries, and spontaneity as key reasons for this choice. Organized trips through agencies are more common for family vacations or when visiting destinations that are less safe or unfamiliar. In some cases, agencies serve as sources of inspiration or information, helping travellers choose destinations and identify tourist spots to avoid.

Participants described a good trip in multifaceted terms. Key elements include the quality of interpersonal relationships. For example, one of the participants noted:

"It is not the location that matters but being with the right people."

Alongside the search for uniqueness and a departure from mass tourism, a minimum standard of comfort, cultural experiences (e.g., museums and architecture), new experiences, broadening horizons, and cuisine. Avoiding crowds and maintaining tranquillity are also essential components. Travel is often characterized as a means of regeneration, mental escape, and personal development, for example:

"With every trip, I get closer to myself."

For most participants, travel is a high priority, as one of the respondents said:

"I could not live without it."

Only a few reported a decline in the importance of travel, attributing it to a shift in life priorities. The high value placed on travel is crucial for understanding their attitudes toward reducing tourism consumption.

4.2 Anticonsumption as Selective and Pragmatic Rather Than Ideological

Participants primarily view the reduction of tourism consumption through a financial lens. They often understand anticonsumption as a cost-saving measure rather than as an environmentally motivated decision. Decisions to reduce consumption often involve weighing costs against perceived benefits, leading individuals to forego activities deemed unnecessary. However, this raises a dilemma regarding the uniqueness of experiences: for example, some might wonder:

"Will I have the opportunity to experience this somewhere else?"

Among unnecessary consumption, the purchase of souvenirs is frequently mentioned. Some participants describe this practice as ritualistic yet functionally unnecessary. They express a distance from excessive material consumption, both at home and while traveling, often rejecting shopping tourism in favour of experiences over ownership. There is also a selective rejection of certain tourism forms, particularly cruises, which some participants view as environmentally and socially problematic. This perception is influenced by concerns about their high environmental impact and limited contributions to the local economy.

Participants believe that the trip's destination and purpose significantly influence the extent of consumption. For nearby destinations, where individuals return for their main seasonal vacations, there is a stronger tendency toward self-sufficiency and more control over costs. In contrast, shorter exploratory trips, often involving air travel, are associated with luggage restrictions and different consumption patterns.

The link between consumption volume and experience quality is not straightforward. Authentic experiences can often be achieved with less consumption and greater engagement with the local environment. However, some participants retrospectively associate higher activity levels and, consequently, greater consumption with richer, fuller experiences.

Reasons for traveling less or consuming less include family obligations, security and political concerns, and environmental considerations. Individuals actively involved in sustainability issues tend to evaluate the necessity of returning to the same destination and the justification for certain travel practices. Additionally, physical fatigue and burnout related to the organization and execution of trips serve as limiting factors.

Although participants express ethical concerns about specific destinations, such as human rights violations or labour exploitation, sustainability issues alone have not been decisive in cancelling trips. Thus, environmentally sustainable behaviour often remains separate from the decision to travel.

Participants indicate that they would be encouraged to reduce consumption primarily due to financial constraints, negative experiences, simplified choices, increased availability of sustainable options, and crowds. Burnout from the logistical and physical demands of travel is also a potential factor in reducing travel. Conversely, participants acknowledge that fatigue can prompt greater consumption as a means of compensating for the effort, such as opting for more comfort during their travels.

4.3 The Persistence of Conspicuous Logic in Experiential Consumption

Participants emphasize that they primarily travel for personal interest, curiosity, and a desire to explore, rather than for social recognition. They often describe their travel identity with terms like 'explorer' or 'adventurer', reflecting an alternative form of self-positioning compared to the traditional signalling of material wealth.

However, discussions reveal an awareness that specific destinations and activities serve as clear status symbols that facilitate status differentiation. These include iconic landmarks, luxury experiences, romantic getaways, and more expensive, media-covered destinations. As one participant explained:

"If you spend that much money to go up the Burj Khalifa, you will definitely want to post a photo on Instagram – just to show how much you spent and that you were there."

Participants believe that the status aspect is particularly amplified by social media, where travel experiences become publicly visible and comparable. They note a connection between higher consumption and an increased likelihood of public exposure on social media.

This discussion highlights the dual function of travel: on one hand, it serves as personal achievement and self-affirmation; on the other, it acts as a means of social signalling. Status signalling has become normalized and is understood as an integral part of contemporary digital culture. Meanwhile, participants express criticism toward those who choose destinations primarily for their symbolic value or publishing ability, distancing themselves from the practice of merely checking off destinations to prove something.

A shift in the perception of status is evident. While status signalling was traditionally associated with spending, participants now recognize that it can also be constructed through thriftiness, resourcefulness, and the ability to organize a high-quality trip on a limited budget. Boasting about low costs and optimization is becoming an alternative form of symbolic positioning. As one participant reflected:

"Back in our student years, many of us would brag about how much we had spent on a trip. Today, you boast about how little money you managed to spend – you even feel embarrassed if you spend more than necessary."

At the same time, there is a tendency to hide high consumption due to feelings of envy, social condemnation, doubts about its legitimacy, or a desire not to make others uncomfortable.

Participants also show a clear rejection of mass destinations and their symbolic value, stating that these have lost their exclusivity due to overexposure. The search for hidden gems serves as a mechanism for differentiation, allowing individuals to share exclusive discoveries and strengthen their identities. However, they acknowledge the paradox that sharing these hidden gems contributes to their popularization. Sometimes, avoiding tourist spots is about seeking more affordable alternatives.

The role of social networks is primarily seen as exploratory and informational. Participants highlight that these platforms help them reduce uncertainty about destinations, provide insights into travel feasibility, and inspire off-the-beaten-path locations. Nonetheless, some admit they follow travel profiles that influence their decisions and often choose destinations recommended by acquaintances because of realistic expectations. There is a desire to distance themselves from trends, though the influence of their social environment remains significant.

Participants cite various motives for traveling, ranging from personal interest to social pressure and the fear of missing out (FOMO). They also differentiate between motives for posting on social media, such as boasting, proving oneself, and preserving memories. In their view, these motives are reflected in the content of their posts.

Lastly, there is an idea that status can be enhanced through reduced consumption or limited travel, especially when this is connected to other symbolic investments (e.g., a car). However, some believe that this form of symbolic positioning through consumption restriction is more easily achievable for public figures or celebrities than for ordinary individuals.

4.4 Indulgence, Contextual Hedonism, and the “Travel Exception”

Participants often view travel as a unique opportunity to step outside the norms of everyday life. This perspective influences how they consume and perceive the value of money. A noticeable shift occurs across different life stages. While travel during student years typically involved minimalism and low expenditure, individuals today, enjoying greater financial stability, tend to indulge in greater comfort. For example, one participant stated:

"I do not go below a certain standard that I have at home because I can afford it when traveling."

Despite this preference for comfort, participants emphasize moderation and reject living beyond their means, promoting conscious consumption.

When traveling, participants notice a change in how they value money. The significance of money takes on a different psychological meaning compared to situations at home. The context of travel, often characterized by limited time, justifies increased spending. There is notable tolerance for expenses and greater budgeting flexibility, particularly when travel is perceived as a rare or once-in-a-lifetime opportunity. Participants often justify their spending with rationalizations, such as stating:

"You only live once," "you must make the most of it while you are there," or "you have to treat yourself; you cannot take anything with you when you die."

These sentiments illustrate a heightened willingness to engage in hedonistic spending while traveling.

Consumption during travel is frequently linked to comfort, safety, time efficiency, and the maximization of overall experiences. Participants face a dilemma between comfort, speed, and responsibility, with their limited travel time often influencing their choices between efficient and comfortable options. Travel also triggers a contextual evaluation of experiences; the same service is often perceived as having a higher subjective value while on vacation than at home, leading to a greater willingness to spend more.

Although participants assert that they generally maintain their values while traveling (for example, by not littering), they also recognize the need to adapt to local customs, sometimes out of concern about standing out. Consequently, environmental standards may be viewed differently based on the context. Behaviour can often be shaped by infrastructure and systemic solutions; when sustainable options are not readily available, individuals may adopt existing practices.

They attribute differences in behaviour while traveling to personality traits. Some believe that responsible individuals maintain consistency in their actions. In contrast, others argue that travel can foster a sense of irresponsibility, as individuals may not perceive the immediate or long-term consequences of their actions.

Their attitudes toward enjoyment and restraint reflect a quest for balance. They endorse indulgence within financial limits, avoid borrowing for travel, and frequently set a flexible daily budget.

Furthermore, participants note a change in routine and an increase in motivation when traveling. They perceive travel as a time for heightened activity and self-reflection. Simultaneously, they recognize that traveling encourages consumption, as they encounter products unavailable or perceived as higher quality than at home. There is often an impulsive logic behind additional purchases, with the thought process like:

"Once you are on a trip, you just tell yourself, just this one more thing."

Such thinking can lead to increased overall spending.

Lastly, participants mention the impact of broader cultural values, particularly collectivist norms, which they believe can promote more sustainable behaviours by emphasising the common good.

4.5 Moral Disengagement as a Central Explanatory Mechanism

This discussion highlights the complex relationship between rationalization mechanisms and emotional responses that influence participants' attitudes toward sustainability and consumption in tourism. Participants describe themselves as a generation with a high level of environmental awareness, understanding the broader social and ecological consequences of tourism. However, their responses reveal a tension between their stated values and actual decisions.

Participants recognize both the positive and negative impacts of tourism. They point out economic benefits for local populations, job creation, and contributions to the development of less developed countries. At the same time, they acknowledge rising property prices, resident displacement, and the unequal distribution of benefits. The conversation often involves weighing these benefits against their costs, with some participants stating that:

"I see more good than bad."

The remark:

"Human selfishness has won at this moment,"

reflects an awareness that personal interests often take precedence over collective responsibility.

Participants often rationalize higher consumption by viewing it as a contribution to the local economy and a beneficial act at the macroeconomic level, stating that:

"Good deeds are rewarded with good."

They frame their consumption as positive and legitimate behaviour.

A significant pattern observed is the transfer of responsibility to the government, regulators, service providers, and the broader system. Participants argue that hotels and cruise lines encourage excessive consumption and that many destinations effectively require higher spending to fully enjoy the experience. They feel that tourists are not solely to blame for the negative impacts of tourism, highlighting the need for systemic solutions such as regulation, infrastructure, and policy changes. Participants express scepticism about the effectiveness of individual voluntary behaviour changes.

Many participants convey a sense of limited individual influence, reflected in statements like:

"It is just a drop in the ocean."

or

"I cannot change anything on my own."

This feeling of powerlessness often leads to a reduced willingness to alter their own behaviour. However, there is also a contrasting belief that individuals can influence broader changes through their demand and set an example for others.

Participants openly acknowledge that they rationalize their decisions, with common justifications including time constraints. One of the participants stated:

"If I am already there, I have to take advantage of it."

We also observed a lack of consideration for efficiency, convenience, comfort, financial accessibility, alternatives, and the complexity of making sustainable choices. They frequently mention adopting selective sustainable practices, mixing more or less sustainable options.

Time savings and affordability often justify air travel. Compensatory behaviour, such as paying environmental taxes, indicates a desire for moral balancing. However, the willingness to engage in compensatory actions depends on the context. For trips that would occur regardless of personal choice, there is a lower likelihood of such behaviour. Participants show selective sensitivity to the price premium for sustainable options, often agreeing to accept minimal additional costs, while higher costs significantly reduce their willingness to choose sustainable alternatives.

Additionally, there is mistrust about how funds collected, such as environmental taxes, are used to address adverse impacts. Participants express scepticism about the information provided and often lack the motivation to verify the tourism's effects independently.

Many participants relativize responsibility for sustainability, arguing that there is always room for even more sustainable actions, which creates an unrealistic, endless standard. At the same time, they highlight the complexity of sustainability decisions, acknowledging that even sustainable choices may come with hidden costs or negative impacts from different perspectives.

Some participants report feeling guilty when opting for unsustainable alternatives, especially when the adverse effects of tourism are emphasized. This guilt is often accompanied by an intention to make different choices in the future. As one participant described:

"Whenever I can, I try to choose differently, but sometimes I'm just exhausted and allow myself an exception. I tell myself that next time I'll do better, but it's not a good feeling when guilt follows you."

Additionally, emotional overload from information about their environmental impact can lead to a sense of distancing from the problem. In some cases, transparency about global unsustainable practices can diminish motivation for sustainable behaviour and reduce the meaningfulness of individual contributions, leading to justifications of their behaviour by comparing themselves to others who are even less sustainable.

Participants also view travel as a time-limited opportunity, associating it with heightened experiences and an increased willingness to spend. In this context, the element of time becomes a more critical consideration in decision-making than financial or environmental factors. Some participants justify their higher travel frequency by referencing their personal histories, such as having taken fewer trips during childhood, which creates a sense of entitlement and legitimacy for their current consumption.

4.5 Conditions for Change and Future Expectations

Participants emphasize that reducing travel intensity and consumption requires increasing awareness of the adverse effects of tourism. They stress the need for greater transparency, verifiability, and clarity of information, which would help build trust in sustainability initiatives and the proper use of collected funds (e.g., environmental taxes). A key aspect for them is the measurability and traceability of effects, as they believe information about tourism's impact is often too complex or dispersed.

According to the participants, they are primarily motivated by sustainability when they can perceive concrete, visible outcomes of change. They highlight the need to simplify data and quantify individual impact, enabling people to understand the consequences of their decisions more clearly. They believe that increased awareness of these consequences would minimize the tendency to ignore or downplay the impact of one's actions.

Moreover, they emphasize the importance of clear rules and institutional mechanisms. Some participants argue that environmental taxes or sustainability measures should be integrated into standard policies, rather than relying on individual choices.

Despite these proposals for change, there is a notable pessimism about future developments. Most participants doubt that attitudes toward travel will shift significantly, especially given rising consumerism and greater travel accessibility. While some believe that first-hand experiences with negative consequences (e.g., climate change) will gradually motivate behavioural change, others are sceptical, suggesting that:

"People will always find an excuse."

Participants also link future developments to the role of the education system, arguing that the impact of such changes will only become evident in the long term. They mention intercultural differences, believing that change is more probable in areas with higher levels of awareness. At the same time, they question whether these changes will spread globally. Additionally, they point out that younger generations have greater choices and convenience, which may further decrease their willingness to limit consumption.

5 Discussion

5.1 Answers to the research questions

This section interprets the findings in relation to the research questions, focusing on the conceptualization of anticonsumption, the mechanisms that sustain the attitude–behaviour gap, and the symbolic factors that influence tourism consumption.

Addressing RQ1, the findings indicate that anticonsumption in tourism is not primarily driven by ideology but is instead justified economically and situationally. This builds upon previous research by illustrating that anticonsumption in tourism manifests as selective and bounded restraint rather than a complete withdrawal from consumption. Travel is viewed as a symbolically protected domain associated with identity, personal regeneration, and value, which limits the impact of sustainability

considerations on behaviour. As a result, anticonsumption is expressed as moderated engagement rather than total avoidance.

In relation to RQ2, the findings indicate that moral disengagement plays a key role in maintaining the gap between environmental awareness and actual tourism behaviour. People are not indifferent; rather, they actively rationalize their choices to maintain a positive moral self-image. This finding extends prior research by highlighting that tourism provides a context in which moral standards can be temporarily relaxed and reinterpreted. While feelings of guilt occasionally emerge, they are typically brief and often neutralized, thereby limiting their potential to drive lasting behavioural change.

Regarding RQ3, the results demonstrate the significant role of symbolic factors in shaping tourism consumption. Even when individuals consciously try to distance themselves from overt status-seeking behaviour, identity signalling continues to play a significant role. This implies that anticonsumption can serve as a symbolic resource, enabling individuals to construct identities based on restraint, authenticity, or resourcefulness. As a result, both consumption and anticonsumption coexist within the same symbolic marketplace, which limits the potential for anticonsumption to bring about substantial changes in tourism practices.

For RQ4, the findings suggest that the willingness to reduce tourism consumption emerges under specific conditions, particularly when faced with financial constraints, fatigue, negative experiences, and the availability of clear, trustworthy, sustainable alternatives. Structural elements such as regulations and default options have a greater influence than voluntary individual motivations. This indicates that behavioural change is dependent on contextual enablers rather than purely value-driven intentions.

5.2 Theoretical contributions

Consistent with prior definitions of anticonsumption as a voluntary, value-driven reduction of consumption (Kropfeld et al., 2018; Iyer & Muncy, 2009), participants engaged in certain forms of consumption restraint. However, these practices were primarily selective and pragmatic rather than ideologically motivated by environmental concerns. Souvenirs, shopping tourism, and cruises were commonly

avoided, yet for reasons related to perceived lack of utility, cost-benefit evaluations, or situational ethical discomfort. Importantly, participants did not question the legitimacy of travel frequency or air transport as such. Rather than rejecting tourism consumption at its core, they targeted peripheral elements. This suggests that, within tourism, anticonsumption rarely manifests as an absolute reduction. Instead, it takes the form of selective moderation within what may be described as a structurally protected consumption domain. Travel functions as a symbolically and emotionally privileged activity, closely tied to identity, regeneration, and social legitimacy. Consequently, reduction efforts remain bounded and negotiated. This reconceptualization implies that anticonsumption in tourism is better understood as symbolically negotiated restraint rather than structural withdrawal. This aligns with research suggesting that environmental motives do not operate in isolation (Cherrier et al., 2010; Ziesemer et al., 2021) but intersect with financial considerations, fatigue, life-stage transitions, and perceived necessity. In a context where travel embodies experiential value and personal growth, sustainability concerns appear insufficient to challenge its core legitimacy.

Although participants explicitly distanced themselves from overt status-seeking behaviour, the findings confirm that tourism remains embedded in the logic of conspicuous consumption (Bronner & de Hoog, 2019). Travel simultaneously functions as personal enrichment and symbolic capital. Even when rejecting luxury-oriented signalling, participants engaged in alternative forms of distinction, emphasizing hidden destinations, authenticity, thriftiness, and resourcefulness. This reflects Effler et al.'s (2022) argument that anticonsumption and conspicuous consumption are not strict opposites. Identity signalling may also occur through restraint. The emergence of status through optimization, such as organizing a high-quality trip at low cost, indicates that symbolic value shifts rather than disappears. Social media further amplifies this dynamic by normalizing visibility, comparison, and the fear of missing out (FOMO). Thus, anticonsumption in tourism operates within the same symbolic marketplace that sustains consumption. Even when travellers deny seeking recognition, structural pressures of visibility and peer comparison shape decision-making. This limits the transformative potential of voluntary restraint and helps explain the persistence of high travel intensity despite environmental awareness.

One of the most notable findings concerns the pervasive role of moral disengagement. In line with Bandura's (1996) framework, participants employed multiple rationalization strategies to reconcile environmental awareness with continued travel. These included moral justification ("*tourism supports local economies*"), diffusion of responsibility (attributing accountability to governments or corporations), moral licensing (offsetting or selective sustainability), and comparative justification (comparing with others who behave worse). The holiday context was consistently framed as an exceptional space governed by different norms. Time scarcity, reward narratives, and once-in-a-lifetime framing legitimized indulgent decisions. Tourism thus creates moral distance, weakening self-regulation mechanisms (Wu et al., 2021; Mkono & Hughes, 2020). Importantly, participants demonstrated reflexive awareness of their rationalizations. This suggests not ignorance, but a motivated negotiation between identity, pleasure, and responsibility. Moral disengagement did not eliminate environmental concern. Instead, it enabled the preservation of a positive moral self-concept without substantial behaviour change ("I will die with a clear conscience, because I did what felt right for me and for the people around me").

Eco-guilt emerged episodically, particularly when environmental consequences were made salient. However, consistent with Nielsen et al. (2024), guilt was often fleeting and neutralized through cognitive reframing. Only when personal responsibility was perceived as direct and unavoidable did guilt appear to strengthen intentions for future change. The findings indicate that moral emotions alone are insufficient to drive durable reductions in tourism consumption. Excessive exposure to environmental problems may even lead to emotional distancing and reduced efficacy, reinforcing defensive coping mechanisms (Stoll-Kleemann & O'Riordan, 2020).

The perspective of the indulgence-restraint dimension provides further insight into this contextual shift. Participants consistently described a shift in the psychological significance of money and consumption while traveling. They justified spending through narratives of deserved reward, rarity, and the maximization of life experiences ("*you only live once*"). Although Slovenia is not generally categorized as a highly indulgent society at the macro level, indulgence orientations were clearly activated in the tourism context. Simultaneously, participants emphasized the importance of moderation and fiscal responsibility, avoiding debt and maintaining

self-imposed limits. Rather than completely abandoning restraint, tourism appears to enable a negotiated form of indulgence – pleasure-seeking intensifies yet remains bounded by perceived legitimacy. This contextual amplification of indulgence suggests that tourism temporarily reorders value hierarchies, prioritizing experiential fulfilment over sustainability norms.

The findings further highlight the ambivalent position of Generation Y. Participants demonstrated strong environmental awareness and openness to systemic solutions, while simultaneously maintaining a strong attachment to frequent travel, experiential intensity, and comfort. This duality aligns with previous research (Holmes et al., 2021; Ziesemer et al., 2021), positioning young consumers as both potential agents of change and active participants in consumption-driven norms. A particularly noteworthy finding concerns the strong emphasis on institutional responsibility. Participants indicated a greater willingness to accept mandatory structural measures (e.g., integrated environmental fees) than to voluntarily restrict their behaviour. Trust, transparency, and measurability were identified as prerequisites for change. When responsibility feels diffuse and has negligible impact, disengagement prevails. These findings suggest that meaningful reductions in tourism consumption depend less on moral persuasion and more on systemic design. Embedding sustainable options into default structures, increasing transparency, and reshaping symbolic norms are more effective than relying solely on individual guilt or awareness.

This study contributes to the literature in three primary ways. First, it reconceptualizes anticonsumption in tourism as a selective and symbolically negotiated restraint rather than an absolute reduction. Second, it demonstrates how moral disengagement, indulgence narratives, and identity signalling interact to sustain the attitudes-behaviour gap within a hedonically privileged consumption domain. Third, it positions tourism as a context in which sustainable values are not abandoned but temporarily reframed, helping to explain the persistence of high travel intensity despite environmental awareness.

5.3 Practical implications

The findings have several important implications for the tourism industry and policymakers. Firstly, strategies to reduce tourism consumption should not rely solely on moral appeals or sustainability messages, as individuals often dismiss them

through a process known as moral disengagement. Instead, interventions should concentrate on structural solutions, including regulations, default options, and integrated pricing mechanisms. Secondly, since financial considerations play a significant role in influencing behaviour, it is crucial to make sustainable options economically viable. Lowering price barriers and increasing cost transparency could enhance their adoption. Thirdly, communication strategies should focus on specific and measurable outcomes. Participants expressed a need for straightforward, verifiable information regarding the environmental impact of their choices, suggesting that vague sustainability messages are insufficient. Lastly, since identity signalling is important in tourism, sustainable behaviour should be positioned as socially desirable and visible. Highlighting the symbolic value of reduced consumption practices may increase their attractiveness.

5.4 Limitations

This study has several limitations. First, it is based on a single focus group of eight participants recruited from an academic environment, limiting the generalizability of the findings. Future research should include more diverse samples across socio-economic and cultural contexts to examine whether similar patterns of negotiated restraint emerge. Second, the qualitative design provides insight into interpretative processes but does not allow for testing the relative influence of mechanisms such as moral disengagement, guilt, or indulgence narratives. Quantitative and experimental studies could assess how these factors shape willingness to reduce tourism consumption. Third, the study relies on self-reported reasoning. Future research could incorporate behavioural or longitudinal approaches to explore discrepancies between stated intentions and actual travel behaviour.

Overall, anticonsumption among young Slovenian travellers emerges as bounded, negotiated, and contextually contingent. Tourism functions as a morally flexible domain in which sustainable commitments are recalibrated rather than rejected. Understanding this flexibility is crucial for designing interventions that move beyond green substitution toward genuine reductions in tourism consumption intensity.

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LABOUR MARKET RESILIENCE AND NEW EMPLOYMENT MODELS IN THE CONTEXT OF DIGITAL AND GREEN TRANSFORMATIONS FOR SUSTAINABLE ECONOMIC DEVELOPMENT

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This paper provides a comprehensive analysis of the impact of digital and green transformations on the structure, functional mechanisms, and employment models of the labor market within the context of sustainable economic development. The application of digital technologies, particularly artificial intelligence, automation, and the platform economy has led to the expansion of flexible and non-traditional forms of work, such as remote work, freelancing, and platform-based employment, while fundamentally transforming the demand for skills in the labor market. At the same time, the green transformation promotes the creation of new “green jobs” in sectors such as renewable energy, energy efficiency, environmentally friendly production, and sustainable logistics, thereby contributing to the establishment of a balance between economic growth and environmental responsibility. The article assesses the opportunities and risks these processes pose for labor market resilience, substantiates the importance of human capital development, lifelong learning, and reskilling mechanisms, and emphasizes the necessity of adapting state policies, institutional reforms, and social protection systems to new employment models.

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1 Introduction

The modern global economy is undergoing profound structural transformation driven by rapid technological advancement, accelerating climate change, and increasing socio-economic complexity. Intensified global competition, resource constraints, and growing environmental risks are compelling countries to shift toward more sustainable and innovation-oriented development models. Within this context, digital transformation and the transition to a green economy have emerged as two interdependent pillars of sustainable economic development, contributing to higher productivity, efficient resource allocation, and improved ecological balance.

These transformations extend beyond the production and service sectors, fundamentally reshaping labor market structures, employment patterns, and the nature of work itself. The expansion of digital technologies facilitates the emergence of new occupational categories and the gradual restructuring of traditional professions, while the green economy generates demand for environmentally sustainable jobs and green skills. However, alongside these opportunities, significant challenges also arise, including skill mismatches, regional inequalities, institutional adaptation gaps, and increasing employment precarity in non-standard work arrangements.

Despite the growing body of literature on digitalization, green transition, and labor market transformation, a key research gap remains insufficiently addressed: the lack of integrated empirical analysis that simultaneously examines how digital and green transformations interact to shape labor market resilience in developing economies, particularly in country-specific contexts such as Azerbaijan. Most existing studies either focus on digital transformation or green economy separately, or rely on general cross-country comparisons without capturing institutional and structural specificities at the national level.

In this regard, the present study aims to address this gap by analyzing how synchronized digital and green transformations influence labor market resilience, employment structure, and emerging forms of work in Azerbaijan. The study specifically seeks to: (1) examine the impact of digitalization and green transition on labor market indicators; (2) identify structural shifts in employment patterns between

2021 and 2024; and (3) assess the role of institutional and policy frameworks in shaping workforce adaptability.

By focusing on a developing economy with ongoing structural reforms, this research contributes to the existing literature by providing a context-specific empirical perspective and by integrating digital and green transformation processes within a unified analytical framework. This allows for a more nuanced understanding of how labor markets evolve under multiple simultaneous transitions, thereby extending current theoretical and empirical discussions in labor economics and sustainable development studies.

2 Theoretical Background / Literature Review

The impact of digital transformation and the green economy on labor markets has become a central issue in contemporary labor economics and development studies. A large body of academic literature argues that technological change is not merely an incremental process but a structural force reshaping employment relations, skill demand, and income distribution. Brynjolfsson and McAfee (2014) emphasize that digital technologies, particularly artificial intelligence and automation, tend to increase productivity while simultaneously contributing to job polarization and wage inequality.

From a theoretical perspective, Autor (2015) introduces the task-based approach, arguing that technological change primarily replaces routine tasks rather than entire occupations. This leads to a polarization of labor markets, where demand increases for both high-skilled cognitive jobs and low-skilled service jobs, while middle-skilled routine occupations decline. This framework provides a more nuanced explanation compared to earlier deterministic views of technological unemployment.

In contrast, Acemoglu and Restrepo (2020) argue that automation can have both displacement and reinstatement effects. While automation reduces demand for certain types of labor, it can also create new tasks and industries. However, they caution that the net employment effect depends heavily on institutional responses, innovation rates, and the ability of economies to generate new labor-intensive activities. This highlights an ongoing academic debate between pessimistic

(displacement-focused) and balanced (reallocation-focused) interpretations of technological change.

Institutional reports such as the World Bank's *World Development Report 2019: The Changing Nature of Work* confirm that digital transformation increases opportunities for productivity growth but also raises significant risks related to inequality, informality, and skill mismatches. Similarly, OECD (2023) findings indicate that while digital adoption improves overall labor market efficiency, countries with weaker education and training systems experience deeper labor market segmentation.

The green economy introduces an additional structural transformation layer. According to the International Labour Organization (ILO, 2023), green transition policies can generate net employment gains, particularly in renewable energy, energy efficiency, and sustainable infrastructure. However, the ILO also stresses that these gains are not automatic and depend on active labor market policies, reskilling programs, and social protection systems. Without such measures, the transition may produce regional and sectoral employment losses, especially in fossil-fuel-dependent economies.

Similarly, IRENA (2024) reports continued growth in renewable energy employment globally. However, academic literature cautions that green job creation is often geographically concentrated and skill-intensive, which may exacerbate regional inequalities if labor mobility is limited. This reflects a broader finding in sustainability economics: environmental transition is simultaneously an economic and distributional process.

In developing and transition economies such as Azerbaijan, World Bank (2024) highlights progress in digitalization, expansion of remote work, and gradual integration into platform-based labor markets. At the same time, empirical studies suggest that structural constraints remain, particularly in terms of skill availability, digital infrastructure, and institutional capacity. OECD-aligned analytical frameworks indicate that such economies often experience a “dual labor market structure,” where high-skilled digital employment coexists with traditional low-productivity sectors.

The green transformation in Azerbaijan is also gradually shaping labor demand. National statistical data (State Statistical Committee of the Republic of Azerbaijan, 2025) indicate growth in environmentally oriented employment programs and vocational training initiatives. However, consistent with global findings, the quality and sustainability of these jobs remain key analytical concerns rather than simply their quantitative expansion.

Overall, the literature suggests that labor market transformation under digital and green transitions should be understood through an integrated theoretical lens combining skill-biased technological change (SBTC), task-based models, and just transition theory. While SBTC explains rising inequality in skill returns, task-based models emphasize structural reallocation of work, and just transition theory introduces normative concerns regarding equity, inclusion, and environmental sustainability.

A key insight emerging from the reviewed literature is that labor market outcomes are not determined solely by technological or environmental change, but by institutional capacity, education systems, and policy design. Countries that invest in lifelong learning, active labor market policies, and digital infrastructure tend to experience smoother transitions and lower inequality costs. Conversely, weak institutional environments tend to amplify displacement effects and increase labor market fragmentation.

In conclusion, contemporary research does not support a single linear narrative of either job destruction or job creation. Instead, it highlights a complex and uneven transformation process in which digitalization and green transition simultaneously generate opportunities and risks. The central challenge for policymakers is therefore not to resist these transformations, but to manage their distributional consequences through inclusive and adaptive labor market institutions.

3 Methodology

This study applies a strengthened mixed-methods research design to overcome the limitations of purely descriptive analysis and to ensure a more rigorous examination of labor market transformations driven by digitalization and green transition processes. In response to methodological concerns regarding the lack of analytical

depth, the study adopts a systematized and operationalized research framework, where both quantitative and qualitative components are clearly defined, structured, and analytically integrated.

The quantitative component is based on a longitudinal analytical design (2021–2024) rather than simple descriptive reporting. Labor market indicators obtained from the State Statistical Committee of the Republic of Azerbaijan (ARDSK, 2025), the World Bank (2024), IRENA & WEF (2024), and TradingEconomics (2025) are analyzed using trend analysis, percentage change calculations, and comparative performance evaluation. This allows for the identification of structural shifts in employment, wage dynamics, and the emergence of digital and green skill-based occupations over time. Additionally, cross-source normalization is applied to ensure comparability across datasets and to reduce measurement bias.

The qualitative component is redesigned as a systematic thematic analysis with an explicit coding procedure, rather than a general document review. Policy documents, labor market strategies, and institutional reports are analyzed using predefined analytical categories, including: (1) labor market governance mechanisms, (2) digital transformation policies, (3) green economy integration strategies, and (4) active labor market programs. This coding-based approach ensures analytical consistency and reduces interpretive ambiguity. Furthermore, qualitative findings are interpreted through relevant theoretical frameworks, including skill-biased technological change and labor market transition theories, allowing for a stronger connection between empirical data and theory.

To address the previously identified methodological weakness, the study implements a formal triangulation strategy. Quantitative trends and qualitative patterns are systematically compared to assess convergence and divergence between statistical evidence and policy narratives. This integration is not merely descriptive but analytical, enabling the identification of causal linkages between institutional interventions and labor market outcomes.

Reliability and validity are enhanced through multiple methodological safeguards, including data triangulation across national and international sources, consistency checks across time-series indicators, and standardized transformation of raw data into comparable metrics such as growth rates and percentage distributions.

Overall, the revised methodological framework moves beyond a descriptive mixed-methods approach and establishes a more structured, transparent, and analytically grounded research design, thereby significantly improving the scientific validity, interpretive depth, and robustness of the study's conclusions.

4 Digital and Green Transformations as Key Drivers of Sustainable Economic Development

Since 2021, the impact of digital and green transformations on the global labor market has become increasingly evident. In the post-COVID-19 period, the adoption of digital technologies accelerated, with remote work and online platforms emerging as key forms of employment. Statistics for 2021 indicate that remote and platform-based work accounted for approximately 15–18% of the global labor market. During the same period, the share of low-skilled traditional jobs declined, while the demand for workers with digital skills increased. In the green transformation domain, 2021 was primarily characterized as a planning and investment phase, with green jobs representing around 8–9% of total employment.

In 2022, the impact of digital transformation on the labor market became more systematic. Employment in the digital economy and technology sectors increased on average by 7–9% compared to the previous year, with demand for specialists in information technology, software development, and data analytics rising sharply. The share of remote and hybrid work models reached 20–22%, while freelancing and platform-based employment expanded rapidly. However, statistics indicate that only about 40–45% of workers in non-standard employment were covered by social protection, highlighting new challenges for labor rights and job stability. In the green transformation sphere, employment in renewable energy and energy efficiency increased by 10–12%, accelerating the development of new job models and professions within the green economy.

By 2023, the impact of digital and green transformations on the labor market was observed with more detailed statistics. Employment growth in digital technology-related professions reached 9–10%, with a sharp increase in demand for workers in artificial intelligence and automation. At the same time, employment in traditional low-skilled sectors declined by 10–15%. The share of remote and platform-based employment rose to 23–24%. Within the green transformation framework, the share

of “green jobs” increased to 11–12%, with notable expansion in waste management and green logistics sectors. This period also highlighted the growing need for upskilling and reskilling programs for the workforce.

In 2024, digital and green transformations are considered to have reached a stage of deep structural changes in the labor market. Statistics indicate that the share of jobs requiring digital skills continued to increase, with annual employment growth in these areas exceeding 10%. The share of remote, freelance, and platform-based employment surpassed 25%. In the green transformation sector, the number of workers in green economy sectors rose by 20–25% compared to 2021, with green jobs becoming a crucial component of labor market resilience. Statistical analyses show that approximately 60% of workers in green sectors required additional upskilling and retraining programs, underscoring the necessity of human capital development and the adaptation of state policies (Gelitashvili, 2024).

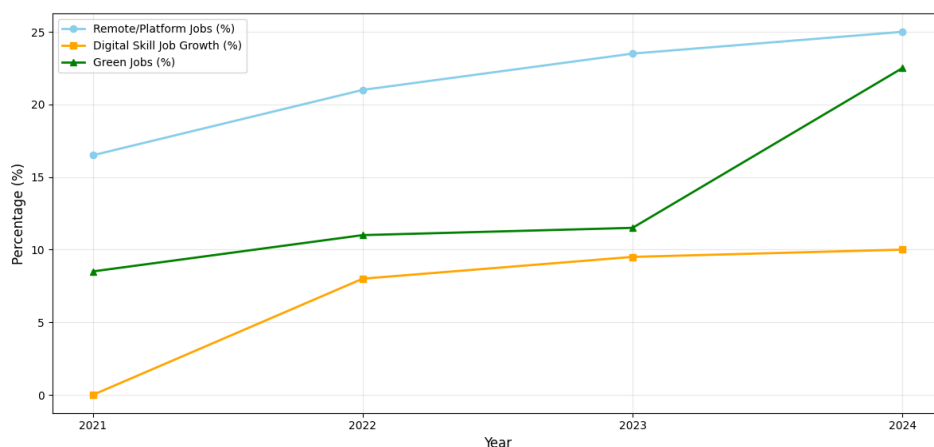


Figure 1: Impact of digital and transformations on the labor market (2021-2024)

Source: Gelitashvili, N. (2024). *The impact of digital transformation on the labor market. Business and Legislation*, 17(2), 38–41. <https://doi.org/10.52340/bal/2024.02.05>

According to Figure 1, transformations in the labor market are clearly observable: remote and platform-based work increased from 16.5% to 25%, jobs requiring digital skills grew by more than 10% annually, and the share of green jobs rose from 8.5% to 22.5%. These indicators confirm that digital and green sectors are the main driving forces of the labor market.

Building on these trends, the *Future of Jobs Report 2025* emphasizes the specific impact of artificial intelligence (AI) on the labor force. According to the report, AI and information processing technologies are expected to create around 11 million new jobs globally while displacing approximately 9 million existing roles by 2030, reflecting a net gain of 2 million jobs attributed solely to AI adoption. The report further indicates that AI-related tasks are increasingly integrated into nearly all sectors, accelerating the demand for digital, analytical, and cognitive skills, while reducing reliance on repetitive and routine manual tasks (World Economic Forum, 2025).

The report also highlights the changing human–machine task distribution. Currently, roughly 47% of work tasks are performed primarily by humans, 22% by machines or algorithms, and the remaining 30% involve human–technology collaboration. By 2030, these proportions are projected to converge toward a more balanced distribution, illustrating the growing role of AI in augmenting human work rather than fully replacing it. This transformation is expected to accelerate the adoption of hybrid employment models, combining AI-enabled platforms with remote, freelance, and green job structures.

In addition, the report emphasizes skill dynamics, noting that around 39–40% of current skills are expected to change significantly by 2030, highlighting the urgency of reskilling and lifelong learning initiatives. These findings align with the observed trends from 2021–2024, in which the rapid growth of AI and digital technologies has already reshaped employment patterns, increased the share of remote and platform-based work, and enhanced the importance of upskilling programs across both digital and green sectors.

Table 1: Impact of Artificial Intelligence (AI) on the Global Labor Force (2024–2030)

Indicator / Metric	2024 (Current)	2030 (Projected)	Change / Note
New jobs created by AI (millions)	–	11	Net gain due to AI adoption
Jobs displaced by AI (millions)	–	9	Replaced primarily routine and repetitive tasks
Net employment change due to AI (millions)	–	2	Net increase in global jobs

Indicator / Metric	2024 (Current)	2030 (Projected)	Change / Note
Human-performed tasks (%)	47	38–40	Decline as AI automation increases
Machine-performed tasks (%)	22	28–30	Increase due to AI integration
Human–AI collaboration tasks (%)	30	32–34	Growth in hybrid work models
Share of jobs requiring digital, analytical, and cognitive skills (%)	30–35	50–55	Rise due to AI-driven demand
Share of routine manual tasks (%)	25–28	15–18	Decrease due to automation
Workforce requiring reskilling/upskilling (%)	25–30	39–40	Significant skill transformation expected
Hybrid employment models (remote/freelance/AI-enabled) (%)	20–25	35–40	Increased adoption globally

Source: World Economic Forum. (2025). *Future of Jobs Report 2025*. Geneva: WEF.

Environmental responsibility represents the fourth pillar of labor market resilience. Green employment generates jobs in environmentally sustainable sectors, making the labor market sustainable not only economically and socially but also environmentally. Globally, the number of green jobs reached 13.7 million in 2022 and 16.2 million in 2023, highlighting the integration of ecological and economic transformations into the labor market (World Economic Forum, 2024).

According to *International Renewable Energy Agency and World Economic Forum (2024)*, a significant increase in global green employment was observed between 2022 and 2023. Green employment, which stood at 13.7 million in 2022, rose to 16.2 million in 2023. This growth demonstrates the crucial role of environmental responsibility in labor market resilience and the increasingly strong integration of the transition to a green economy into employment structures. Consequently, green employment contributes to the formation of a labor market that is sustainable both environmentally and economically.

The relationship between new employment models and labor market resilience develops gradually and sequentially. Remote and hybrid employment models enhance economic agility while promoting social inclusiveness, facilitating the integration of diverse social groups into the labor market. Platform-based employment and freelancing stimulate human capital development, improve the efficient use of labor resources, and increase overall market productivity. At the same time, green employment reinforces the principle of environmental responsibility, highlighting the ecological dimension of the labor market. The complementarity of these employment forms results in a labor market that functions as a complex, flexible, and resilient system.

In this regard, there is a strong and interdependent relationship between labor market resilience and new employment models. While new employment models strengthen market agility, social inclusiveness, the quality of human capital, and environmental responsibility, a resilient labor market provides the institutional and regulatory framework necessary for the effective implementation of these models. Thus, the labor market gradually evolves from being merely a mechanism for allocating economic resources to also serving as a guarantor of social welfare and ecological sustainability.

Taken together, these data confirm that AI, alongside broader digital and green transformations, is a key driver of structural changes in the global labor market, shaping not only the number of jobs but also their quality, skill requirements, and employment modalities. Consequently, ensuring labor market resilience increasingly depends on integrated policies that promote workforce adaptability, human capital development, and alignment with sustainable employment models.

4.1 Economic Agility in Azerbaijan

Economic agility ensures the labor market’s resilience to shocks. For instance, during the COVID-19 pandemic, many sectors experienced job losses and reduced working hours. These challenges were particularly pronounced in 2021 and 2022. However, in 2023 and 2024, the global and local economic recovery accelerated, unemployment levels declined, and wages increased. Globally, unemployment was approximately 5% in 2023 and 4.9% in 2024, while employment in Azerbaijan reached 94.5% in 2023 and 94.7% in 2024. These statistics demonstrate that market agility is a key element of labor market resilience (TradingEconomics, 2025).

Table 2: Key labor market indicators for Azerbaijan, 2021–2024

Year	Unemployment Rate (AZ)	Employment Rate (AZ)	Average Monthly Wage (AZN)
2021	5.3%	93.8%	800
2022	5.0%	94.2%	850
2023	4.9%	94.5%	900
2024	4.7%	94.7%	950

Source: TradingEconomics. (2025). Azerbaijan unemployment rate. Trading Economics. <https://tradingeconomics.com/azerbaijan/unemployment-rate>

The statistical dynamics presented in Table 2 indicate that the Azerbaijani labor market is shaped not only by economic indicators but also in accordance with the principles of social inclusiveness and human capital development. State policies, institutional mechanisms, and new employment models complement each other to ensure the long-term resilience of the labor market.

The principle of social inclusiveness supports the economic agility of the labor market from a social perspective. The participation of all social groups regardless of age, gender, education, or region stabilizes the labor market and promotes social equity. Remote and hybrid employment models strengthen this principle by removing geographical barriers and providing job opportunities for people living in remote areas. These models also enhance workers' technological skills and accelerate the development of a digital labor market.

The table below shows the share and growth rates of various employment models in the labor market from 2021 to 2024 (World Bank, 2024).

Table 3: Share of New Employment Models in the Azerbaijani Labor Market, 2021–2024

Employment Model	2021 (%)	2024 (%)	Growth (%)
Remote and Hybrid Work	16.5	25	8.5
Platform-Based Employment	16.5	25	8.5
Jobs Requiring Digital Skills	10	22	12
Green Jobs	8.5	22.5	14

Source: World Bank. (2024). Digital Skills for Azerbaijan
<https://documents1.worldbank.org/curated/en/099621006292298672/pdf/P17756509a1fdc0608d2e0f206d42fc6b6f.pdf>

As shown in the table, between 2021 and 2024, the share of remote and hybrid work, as well as platform-based employment models, increased by 8.5 percentage points, reaching 25%. This indicates a rise in the social inclusiveness of the labor market and the diminishing impact of geographical boundaries on employment opportunities.

The share of jobs requiring digital skills grew from 10% to 22%, clearly demonstrating the impact of digital transformation on workers' skills and the agility of the labor market.

The share of green jobs increased from 8.5% to 22.5%, reflecting both the implementation of the principle of environmental responsibility in the labor market and the rapid development of the green economy.

Human capital development further strengthens labor market resilience. Digital transformation and new employment models create opportunities for workers to enhance professional skills and expand reskilling and upskilling programs. Platform-based employment, freelancing, and flexible work schedules allow employees to work on diverse projects and broaden their skill sets. This not only enhances the adaptability of individual workers and companies to the market but also stimulates productivity and innovation.

Labor market resilience is ensured not only through economic indicators but also through the coordinated operation of state policies and institutional mechanisms in Azerbaijan. The integration of economic agility, social inclusiveness, and environmental responsibility is a key priority for state regulation of the labor market. Within this framework, the state ensures long-term labor market flexibility and productivity by developing a regulatory framework compatible with new employment models, fostering human capital, and strengthening social protection mechanisms.

Education and human capital development are emphasized as one of the main pillars of this strategy. In 2021–2022, the enhancement of digital skills and innovative disciplines in educational institutions accelerated the training of personnel in line with the changing labor market demands. In parallel, active employment programs supported the vocational training and retraining of unemployed individuals, improving the alignment between labor supply and demand. In 2023–2024, the scope of reforms in education and vocational training further expanded, with the implementation of programs in new specializations requiring digital and green skills, enabling workers to adapt flexibly to the labor market, thereby significantly increasing productivity and innovative capacity.

Digital transformation is one of the key factors strengthening labor market resilience. In 2021–2022, the introduction of digital platforms and e-services, along with the promotion of remote and hybrid work models, accelerated worker adaptation to work processes. In 2023–2024, demand for workers with digital skills

increased, new jobs were created, and the labor market was aligned with innovative employment models. These changes not only enhanced worker productivity but also ensured market agility and adaptation to the digital economy.

Azerbaijan's green economy initiatives play a vital role in the sustainable development of the labor market. In 2021–2022, initial projects in renewable energy and energy efficiency were implemented, and in 2023–2024, solar and wind energy projects were expanded, creating new jobs. State-organized training and vocational programs in this sector increased workers' knowledge and skills in the green economy, expanding access to the labor market. As a result, demand for workers with green skills increased, and environmental responsibility was strengthened (Trend News Agency, 2025).

Table 4: Key Indicators and Impact of Active Employment Measures in Azerbaijan, 2021–2024

Indicators	2021–2022	2023	2024
Number of people covered by active employment measures	350,000	380,000	396,700
Number of people employed	–	–	160,000+
Number of participants in self-employment programs	–	–	17,300
Main focus areas	Vocational training, retraining	Skills enhancement, reintegration	Employment provision, self-employment
Impact on the labor market	Agility and adaptation	Active reintegration	Sustainable employment models

Source: Trend News Agency. (2025, January 9). *Azerbaijan discloses number of individuals benefiting from active employment measures in 2024*. <https://www.trend.az/business/3991457.html>

Active employment programs are also a key mechanism enhancing labor market agility and resilience. In 2021–2022, approximately 350,000 individuals participated in active employment initiatives through vocational training and retraining programs for the unemployed. In 2023, this number increased to 380,000, supporting skill enhancement and reintegration into the labor market. By 2024, 396,700 individuals were covered by active employment programs, with over 160,000 placed in jobs and 17,300 engaged in self-employment programs. These results demonstrate the strong impact of state policy on the labor market and the effectiveness of new employment

models. Social protection mechanisms have been adapted to remote, platform-based, and freelance work, ensuring the protection of workers’ rights.

Between 2021 and 2024, other indicators in the labor market also showed significant improvement. The employment rate reached 93.8% in 2021, 94.2% in 2022, 94.5% in 2023, and 94.7% in 2024. During the same period, the unemployment rate continued to decline, falling from 5.3% in 2021 to 5.0% in 2022, 4.9% in 2023, and 4.7% in 2024. The average monthly wage increased from 800 AZN in 2021 to 850 AZN in 2022, 900 AZN in 2023, and 950 AZN in 2024.

The number of workers with digital and green skills grew from 120,000 in 2021–2022 to 150,000 in 2023, and reached 175,000 in 2024. These indicators clearly demonstrate that the labor market has developed both in quality and quantity, has adapted to digital and green transformations, and reflects the effectiveness of state policy (ARDSK 2025).

Table 5: Key Labor Market Indicators and Workforce with Digital and Green Skills in Azerbaijan, 2021–2024

Indicators	2021	2022	2023	2024
Employment Rate (%)	93.8	94.2	94.5	94.7
Unemployment Rate (%)	5.3	5.0	4.9	4.7
Average Monthly Wage (AZN)	800	850	900	950
Number of Workers with Digital and Green Skills	120,000	120,000	150,000	175,000

Source: State Statistical Committee of the Republic of Azerbaijan. (2025). Labor market – employment and labor indicators. <https://www.stat.gov.az/source/labour/>

Thus, in the Republic of Azerbaijan, state policy and institutional mechanisms serve as key instruments for ensuring the sustainable development of the labor market. Aligning the education system with labor market demands, developing digital and green skills, implementing active employment programs, and adapting social protection mechanisms strengthen the labor market’s economic agility, social inclusiveness, human capital development, and environmental responsibility. The measures undertaken between 2021 and 2024 demonstrate that state policy plays a crucial role in modernizing the labor market, supporting sustainable development, facilitating the adoption of new employment models, and enabling workers to adapt to market needs.

5 Discussion

The analysis of Azerbaijan's labor market transformation within the context of digital and green transitions indicates that observed trends generally align with expected theoretical assumptions regarding technological change and sustainability-driven employment restructuring. However, limiting the interpretation solely to the confirmation of expected trends would oversimplify the complexity of ongoing structural changes. A more rigorous assessment suggests that labor market outcomes are shaped by a combination of institutional, structural, and external factors, which introduce important limitations to the observed developments.

One key limitation of the current findings is the strong dependence on aggregated macro-level indicators, which may mask significant intra-sectoral and regional disparities. While national statistics indicate improvements in employment structure and skill alignment, these improvements are not necessarily uniform across different regions, industries, or demographic groups. In particular, disparities in access to digital infrastructure and training opportunities may lead to uneven distribution of the benefits of transformation processes.

An alternative explanation for some of the observed labor market improvements may lie in broader macroeconomic dynamics, including post-pandemic recovery effects and fluctuations in global energy markets. These external factors can temporarily influence employment rates and wage levels, potentially overstating the structural impact of digitalization and green transformation policies if not carefully disentangled from long-term trends.

Furthermore, while policy initiatives in digital skills development and green employment programs have expanded, their effectiveness should be interpreted with caution. Implementation gaps, limited institutional capacity in certain regions, and differences in program accessibility may reduce the overall impact of these reforms. This suggests that policy presence does not automatically translate into uniform labor market outcomes, highlighting the importance of governance quality and implementation efficiency.

From a broader theoretical perspective, the findings reinforce but also partially challenge dominant assumptions in labor market transition theories. While skill-biased technological change and green transition frameworks predict increased demand for high-skilled labor, the emergence of platform-based and non-standard employment forms introduces additional complexity. These employment models may increase flexibility but also raise concerns regarding job security, income stability, and social protection coverage, which are not fully captured in conventional employment indicators.

In terms of broader implications, Azerbaijan's experience suggests that labor market resilience should be understood as a multidimensional concept that includes not only adaptability to technological and environmental change but also inclusiveness, institutional capacity, and social equity. Without addressing these dimensions, the benefits of transformation risk being unevenly distributed, potentially reinforcing existing structural inequalities.

6 Conclusion

Overall, while the findings confirm the general direction of expected labor market transformations under digital and green transitions, a deeper critical analysis reveals important constraints, alternative causal explanations, and distributional effects. These factors highlight that labor market resilience is not an automatic outcome of technological or environmental change but rather a contingent process shaped by policy design, institutional effectiveness, and socio-economic context.

By incorporating these critical dimensions, the study moves beyond descriptive validation and contributes to a more nuanced academic understanding of how digitalization and green transformation interact with labor market structures in developing economies such as Azerbaijan. This strengthens the study's analytical depth and enhances its potential as a meaningful academic contribution.

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JUST TRANSITION IN EUROPEAN COAL REGIONS: COMPARATIVE ANALYSIS OF GOOD PRACTICES UNDER THE EUROPEAN GREEN DEAL

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The phase-out of coal represents a major structural transformation for coal-dependent regions in the European Union, with significant socio-economic implications for regional labour markets, economic structures, and demographic stability. This study examines the just transition process in selected European coal regions using a comparative case-study methodology. The analysis focuses on four key dimensions of transition performance: governance capacity, labour-market outcomes, economic diversification, and demographic trends. To enhance analytical consistency, the paper introduces a qualitative Just Transition Performance Index (JTPI), which integrates these dimensions into a structured comparative framework. Based on empirical evidence and index-based interpretation, the study develops a typology of coal regions, distinguishing structurally resilient regions, transitional regions with mixed outcomes, and socially vulnerable regions. The findings contribute to the understanding of regional transition dynamics and highlight the importance of institutional capacity, strategic planning, and economic diversification for achieving sustainable and socially balanced transition outcomes.

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1 Introduction

The transition towards climate neutrality represents one of the most profound structural transformations in the history of the European Union. With the adoption of the European Green Deal (EGD), the European Commission established a comprehensive growth strategy aimed at transforming the Union into a modern, resource-efficient, and competitive economy, while achieving net-zero greenhouse gas emissions by 2050. This strategic framework goes beyond environmental policy, as it fundamentally reshapes economic structures, labour markets, regional development patterns, and public finance systems across Member States.

A central pillar of the EGD is the accelerated reduction of greenhouse gas emissions, with an intermediate target of at least a 55 per cent reduction by 2030 compared to 1990 levels. Achieving these ambitious objectives requires the rapid transformation of energy systems, particularly through the gradual phase-out of coal, which remains one of the most carbon-intensive energy sources. Despite a long-term declining trend, coal has historically played a crucial role in Europe's industrial development and energy security, and in several Member States it continues to represent a significant component of electricity and heat production (Eurostat, 2024c). The structural importance of coal has resulted in strong regional dependencies. Coal mining regions have often developed highly specialised economic structures, characterised by concentrated employment, strong linkages with energy-intensive industries, and long-established social identities connected to mining activities. Consequently, the phase-out of coal does not merely constitute an energy transition, but represents a deep socio-economic transformation affecting employment, income stability, demographic trends, and long-term regional competitiveness. Without adequate policy intervention, these processes risk exacerbating regional disparities and social inequalities within the EU (European Commission (EC), 2019, 2021).

In response to these challenges, the concept of the just transition has emerged as a central normative and policy framework of the EGD. The just transition seeks to ensure that the shift towards climate neutrality is fair and inclusive, minimising adverse social impacts on workers and communities most affected by the decarbonisation process. Its core principle, often summarised by the slogan “leaving no one and no region behind”, emphasises the need to combine environmental

objectives with social cohesion, economic diversification, and active labour-market policies (ILO, 2015; McCauley & Heffron, 2018; Heffron et al., 2020).

Recognising that coal-dependent regions face significantly higher adjustment costs, the European Union has developed a targeted policy architecture to support their transformation. Within the framework of the Just Transition Platform, the Just Transition Mechanism (JTM) was introduced for the 2021–2027 programming period. The mechanism integrates multiple financial instruments, including the Just Transition Fund, a dedicated Invest-EU scheme, and a public sector loan facility supported by the European Investment Bank. Together, these instruments aim to mobilise substantial public and private investments to facilitate economic restructuring, promote innovation, support skills development, and strengthen social resilience in the most affected territories (EC, 2020, 2021). However, the implementation of the just transition remains highly uneven across the EU. Coal regions differ significantly in terms of economic structure, institutional capacity, demography, labour-market conditions, and governance arrangements. While some regions have managed to combine coal phase-out with economic diversification and social stabilisation, others continue to struggle with persistent unemployment, population decline, limited private investment, and delayed implementation of transition strategies. These differences underline the importance of analysing practical experiences and identifying transferable good practices that may inform future policy design (European Court of Auditors, 2022; OECD, 2021).

Against this background, the purpose of this chapter is to provide a comparative analysis of selected European coal regions that have already entered advanced stages of the coal phase-out process and to address the following research question: how do governance capacity, labour-market adjustment, economic diversification, and demographic trends influence the effectiveness of just transition processes in European coal regions? Focusing on regions within the European Union, the chapter examines how different policy approaches, financial instruments, and governance models have influenced socio-economic outcomes during the transition. The analysis combines a comparative case-study approach with a qualitative assessment framework to identify structural patterns and policy-relevant insights. Particular attention is devoted to the role of European structural and investment funds, national support schemes, and local stakeholder involvement in shaping regional transformation trajectories. The selected regions were chosen based on their

relevance for comparative analysis and their degree of similarity to coal-dependent regions currently undergoing transition, including the SAŠA region in Slovenia. By examining cases from Germany, Poland, the Czech Republic, Romania, Spain, and Slovakia, the chapter aims to identify common patterns, key challenges, and effective policy responses associated with the just transition process. The central objective of this chapter is therefore twofold. First, it seeks to systematise empirical evidence on socio-economic restructuring in former coal regions and evaluate the effectiveness of different transition instruments. Second, it aims to derive policy-relevant lessons that may support regions which are still at the early stages of coal phase-out. By doing so, the chapter contributes to the broader debate on the EGD as a development strategy and highlights the importance of aligning climate objectives with social cohesion and long-term regional sustainability (McCauley & Heffron, 2018). The remainder of the chapter is structured as follows. Section 2 introduces the conceptual framework of the just transition and its key socio-economic dimensions. Section 3 presents the European policy context and financial instruments supporting the transition. Section 4 outlines the methodological approach and criteria for selecting the analysed regions. Section 5 provides a comparative analysis of selected coal regions across the EU. Section 6 synthesises good practices and key lessons derived from the empirical cases. Section 7 discusses implications for coal regions currently in transition, while Section 8 concludes the chapter with final reflections and directions for future research.

2 Conceptual framework of a Just Transition

The concept of the just transition has gained increasing prominence in international climate and energy policy debates over the past two decades. Initially developed within labour movements and later adopted by international organisations, the notion of a just transition reflects the recognition that climate policies, while environmentally necessary, may generate substantial social and economic costs if not carefully designed. As such, the just transition represents an integrative framework that seeks to reconcile environmental sustainability with social justice and economic stability (McCauley & Heffron, 2018). At its core, the just transition is founded on the principle that the shift towards a low-carbon economy should not disproportionately burden specific social groups or territories. Regions highly dependent on fossil fuel extraction and carbon-intensive industries face particularly high adjustment costs, including job losses, declining regional incomes, demographic

outmigration, and erosion of local economic structures (OECD, 2021). Without targeted policy interventions, these dynamics risk deepening existing regional disparities and undermining public support for climate action. From a conceptual perspective, the just transition can be understood as a multidimensional process encompassing economic, social, institutional, and territorial dimensions.

The economic dimension relates to the restructuring and diversification of regional economies, including the development of alternative industries, support for entrepreneurship, and attraction of new investments. The social dimension focuses on employment protection, income security, skills development, and the prevention of social exclusion, particularly among workers directly affected by industrial decline. The institutional dimension emphasises governance capacity, coordination between different levels of government, and the effective use of policy instruments. Finally, the territorial dimension highlights the spatial concentration of transition impacts and the need for place-based policy responses (ILO, 2015, EC, 2019). A central element of the just transition framework is the labour-market adjustment process. Coal phase-out often results in concentrated employment shocks that cannot be absorbed through market alone. Consequently, active labour-market policies play a crucial role, including retraining and reskilling programmes, career counselling, mobility support, and targeted employment incentives. Empirical evidence suggests that early intervention, tailored training schemes, and strong cooperation with employers significantly improve re-employment outcomes for displaced workers (OECD, 2021). Beyond labour-market measures, social dialogue constitutes another foundational pillar of the just transition. The involvement of trade unions, employers' associations, local authorities, civil society organisations, and affected communities enhances the legitimacy and effectiveness of transition strategies (ILO, 2015). Inclusive governance arrangements allow for the identification of local needs, increase policy acceptance, and reduce resistance to structural change. In this regard, the just transition is not solely a technical or economic process but also a participatory one, requiring continuous engagement among stakeholders. The territorial nature of the just transition further implies that uniform policy solutions are unlikely to be effective. Coal regions differ considerably in terms of population size, industrial legacy, infrastructure quality, human capital, and innovation capacity. For this reason, the just transition is closely linked to the concept of place-based development, which emphasises tailored strategies reflecting local strengths, constraints, and development potentials. Such an approach aligns with the broader

objectives of European cohesion policy, which aims to reduce regional disparities while supporting structural transformation (OECD, 2021). Within the European Union, the just transition has been explicitly integrated into the strategic framework of the EGD. The principle of “leaving no one and no region behind” underscores the political commitment to ensuring that decarbonisation contributes to inclusive growth rather than social fragmentation. This commitment reflects the understanding that climate neutrality can only be achieved sustainably if it is socially acceptable and economically viable across all Member States (EC, 2019, 2021). Importantly, the just transition framework also entails intertemporal considerations. Transition costs are often immediate and highly visible, whereas the benefits of decarbonisation, such as environmental improvements, innovation-driven growth, and enhanced energy security, materialise gradually over time. Public policy therefore plays a critical role in smoothing adjustment processes and distributing costs more evenly across society and generations (OECD, 2017). In this context, fiscal instruments, public investment, and European solidarity mechanisms become essential tools for mitigating short-term disruption while enabling long-term structural transformation. Strategic public investment can act as a catalyst for innovation and new industrial development in transition regions (Mazzucato, 2013). Another key conceptual distinction concerns the difference between energy transition and socio-economic transition. While energy transition primarily focuses on replacing fossil fuels with renewable energy sources, the just transition adopts a broader perspective encompassing economic restructuring, social cohesion, and regional development (McCauley & Heffron, 2018). Empirical experiences from coal regions demonstrate that replacing energy sources alone does not automatically generate sufficient employment or income opportunities (EC, 2020). Successful transitions therefore require comprehensive development strategies extending beyond the energy sector, including innovation support, entrepreneurship, and human capital investment (OECD, 2021). In this sense, the just transition framework emphasises the importance of long-term strategic planning. Regions that initiated transition strategies early, invested in education and innovation, and established strong institutional coordination mechanisms have generally demonstrated greater resilience. Conversely, regions characterised by delayed planning, fragmented governance, and reliance on short-term compensatory measures have faced prolonged socio-economic difficulties.

In summary, the just transition represents a holistic policy paradigm that integrates environmental ambition with social responsibility and territorial cohesion. It provides the conceptual foundation for understanding why coal phase-out must be accompanied by targeted support mechanisms and coordinated governance structures. This framework underpins the empirical analysis presented in the subsequent sections of this chapter, which examine how different European coal regions have operationalised the principles of the just transition in practice.

3 European Green Deal and EU Financial Instruments

The European Green Deal (EGD) represents the most comprehensive policy framework adopted by the European Union in the field of climate and sustainable development. Introduced in 2019, it establishes a long-term vision of transforming the European economy into a climate-neutral, resource-efficient, and globally competitive system. Unlike earlier policy initiatives, the EGD explicitly integrates climate objectives with economic transformation, industrial development, and social cohesion. Its central goal—climate neutrality by 2050—is complemented by an intermediate target of reducing greenhouse gas emissions by at least 55 per cent by 2030 compared to 1990 levels (European Commission, 2019, 2021). Achieving these objectives requires structural changes across multiple sectors, with the energy sector playing a particularly critical role due to the high emission intensity of fossil fuels, especially coal. Coal phase-out has therefore become a key component of EU decarbonisation policy. However, the EGD recognises that the socio-economic costs of this transformation are unevenly distributed, with coal-dependent regions facing disproportionately high adjustment pressures. This asymmetry underpins the development of targeted policy instruments aimed at supporting affected regions (European Court of Auditors, 2022). To operationalise the principle of a fair transition, the European Commission established the Just Transition Platform, which provides technical assistance, facilitates knowledge exchange, and supports the preparation of Territorial Just Transition Plans. These plans play a central role in defining region-specific transition pathways and are a prerequisite for accessing dedicated financial support. Building on this framework, the Just Transition Mechanism (JTM) was introduced for the 2021–2027 programming period as a comprehensive financial architecture designed to address the socio-economic impacts of decarbonisation. The JTM combines three complementary instruments.

The first pillar of the JTM is the Just Transition Fund (JTF). The fund provides targeted grants to regions facing the most severe employment and economic challenges arising from the transition away from fossil fuels. Its primary objectives include supporting economic diversification, facilitating the creation of new sustainable jobs, financing reskilling and upskilling programmes, and promoting the rehabilitation of industrial sites. Importantly, the JTF is embedded within cohesion policy and operates under a place-based logic, allowing Member States to tailor interventions to regional characteristics. National co-financing requirements further enhance ownership and integration with broader development strategies (EC, 2021).

The second pillar consists of a dedicated Just Transition scheme under the Invest-EU programme. This component aims to leverage private investment by providing EU budget guarantees to reduce investment risk in transition regions. Through financial instruments such as loans, equity, and guarantees, the Invest-EU Just Transition scheme supports projects in areas including renewable energy, clean mobility, energy efficiency, innovation, and business development. By crowding in private capital, this pillar seeks to complement grant-based support and strengthen the long-term sustainability of regional economies (EC, 2020, 2021).

The third pillar of the mechanism is the Public Sector Loan Facility, implemented in cooperation with the EIB. This instrument combines EU grants with EIB loans to support public-sector investments that do not generate sufficient market returns but are essential for regional transformation. Typical projects include energy infrastructure, heating systems, public transport, environmental rehabilitation, and social infrastructure. By lowering borrowing costs for regional authorities, the facility enhances the capacity of public institutions to act as catalysts of transition. Together, these instruments reflect a shift from compensatory policies towards investment-driven development strategies. The mechanism represents a transition from reactive adjustment policies towards proactive transformation strategies (EC, 2021).

Despite this comprehensive financial architecture, the effectiveness of EU instruments depends critically on governance capacity at national and regional levels. Access to funding requires coherent transition planning, institutional coordination, and the ability to develop viable projects. Regions with stronger administrative capacity are therefore better positioned to utilise available resources, while weaker regions risk delays or underutilisation. Moreover, the scale of investment required

for climate neutrality exceeds the resources provided by the JTM alone. National budgets and private investment remain essential components of the overall financing framework (European Commission, 2021; OECD, 2021). In this context, EU funds act primarily as catalytic instruments that guide investment priorities and reduce transition risks, rather than as substitutes for national commitment. In summary, the EGD and its associated financial instruments constitute a multi-level governance framework aimed at aligning climate objectives with social cohesion and regional development. The extent to which this framework translates into successful regional transformation ultimately depends on institutional capacity, policy coherence, and effective implementation at national and regional levels.

4 Methodological Approach

This chapter adopts a qualitative comparative case-study approach to examine the socio-economic dimensions of the just transition in selected European coal regions. The methodological design is grounded in the recognition that coal phase-out processes are deeply embedded in regional economic structures, institutional arrangements, and historical development paths, which cannot be adequately captured through purely quantitative modelling.

A comparative case-study methodology enables an in-depth exploration of heterogeneous transition trajectories and facilitates the identification of patterns, similarities, and differences across regions. This approach is particularly suitable for analysing complex policy processes involving multiple governance levels, diverse funding instruments, and region-specific socio-economic conditions. By combining structured comparison with qualitative interpretation, the methodology provides both analytical depth and policy relevance.

4.1 Selection of Regions

The selection of regions was guided by three main criteria. First, the analysed regions have experienced significant dependence on coal mining and coal-based energy production, resulting in substantial employment and structural impacts following the decline or closure of mining activities. Second, the regions have entered advanced or completed stages of coal phase-out, enabling the assessment of observed transition outcomes rather than projected effects. Third, the regions exhibit varying

institutional, economic, and demographic characteristics, allowing for meaningful comparison across different transition models. Based on these criteria, the chapter focuses exclusively on coal regions located within EU. This limitation reflects both data availability and the intention to analyse transition processes within a common policy framework shaped by the EGD and EU cohesion policy instruments. The analysed regions include Lusatia in Germany, Malopolska and Silesia in Poland, the Moravian-Silesian Region in the Czech Republic, the Jiu Valley in Romania, Asturias and León–Palencia in Spain, and Upper Nitra in Slovakia. Special attention is devoted to the comparability of these regions with coal-dependent regions currently undergoing transition, including the SAŠA region in Slovenia. Although the regions differ in size and demographic structure, their shared dependence on coal-related economic activities provides a robust basis for comparative analysis.

4.2 Data Sources

The analysis is based on secondary data obtained from multiple European and national sources. Key quantitative indicators were drawn from Eurostat databases, including data on coal production, employment in mining activities, demographic trends, and labor-market developments (Eurostat, 2024abc). Additional information was collected from reports published by the European Commission and the Joint Research Centre, which provide detailed assessments of coal regions in transition (EC, 2020). Evaluations of EU financial instruments and implementation effectiveness were informed by reports of the European Court of Auditors (2022). Policy documents, regional development strategies, territorial just transition plans, and evaluation reports of European Structural and Investment Funds were also examined. These sources enabled an assessment of both formal policy design and practical implementation. Where available, regional-level statistics were complemented by qualitative information on governance structures, stakeholder involvement, and strategic planning processes.

4.3 Analytical Framework and Construction of JTPI

The comparative analysis is structured around four core analytical dimensions reflecting the key components of the just transition process identified in the conceptual framework like governance capacity (institutional coordination, strategic planning, implementation effectiveness), labour-market outcomes (employment

adjustment, job creation), economic diversification (innovation, investment structure, SME development) and demographic trends (migration patterns and population stability). These dimensions capture the structural and institutional determinants of transition performance and provide a consistent basis for cross-regional comparison. To support a more systematic interpretation of comparative results, a simple Just Transition Performance Index (JTPI) is constructed in section 6. The index aggregates the four analytical dimensions using a qualitative scoring approach. The index provides a synthetic measure of relative transition performance across cases. It is important to emphasise that the JTPI is not intended as a statistically rigorous composite indicator, but rather as a heuristic and interpretative tool. Its purpose is to enhance transparency, facilitate structured comparison, and support the synthesis of findings presented in the empirical analysis and complements the qualitative assessment.

4.4 Limitations of the Study

Several limitations should be acknowledged. First, the availability and comparability of regional data remain uneven, particularly regarding indirect employment effects and long-term socio-economic impacts. Second, differences in national statistical methodologies constrain direct quantitative comparison across regions. Third, the analysis focuses primarily on observable short- to medium-term outcomes, while many transition effects will materialize only over longer time horizons. Despite these limitations, the comparative case-study approach provides valuable insights into practical transition experiences and supports the identification of policy-relevant lessons. The findings should therefore be interpreted as indicative rather than deterministic, highlighting tendencies and good practices rather than universal causal relationships.

5 Comparative Analysis of Selected European Coal Regions

This section presents a comparative analysis of selected European coal regions that have entered advanced stages of the coal phase-out process. The analysis focuses on socio-economic adjustment mechanisms, governance arrangements, and the effectiveness of policy instruments applied during the transition. By examining different regional trajectories, the section aims to identify structural patterns and practical experiences that contribute to varying just transition outcomes.

To provide a structured overview of initial conditions and transition dynamics, Table 1 summarises key indicators, including demographic characteristics, coal-sector employment trends, production dynamics, and the scope of labour-market adjustment measures. The data are primarily derived from Eurostat databases and European Commission reports on coal regions in transition (EC, 2020; Eurostat, 2024a, 2024b).

Table 1: Comparative overview of selected European coal regions

Indicator	Lusatia (DE)	Małopolska (PL)	Silesia (PL)	Moravian-Silesian (CZ)	Jiu Valley (RO)	Palencia & León (ES)	Asturias (ES)
NUTS level	NUTS 3	NUTS 2–3	NUTS 2	NUTS 2	NUTS 2–3	NUTS 3	NUTS 2
Population (million)	0.6	3.4	4.5	1.2	0.1	0.6	1.0
Coal employment 2014	3,600	4,921	93,190	14,749	4,741	1,113	2,400
Coal employment 2020	3,323	3,814	71,281	6,818	3,056	0	0
Jobs lost (2014–2020)	277	1,107	21,909	7,931	1,685	1,113	2,400
Coal production (Mt)	33.0	5.0	49.4	4.5	0.7	0.5	0.3
Active mines (2022)	2	2	16	1	4	0	0
Participants in retraining programmes	1,936	65,170	12,234	6,276	1,823	884	7,990
Jobs created via ERDF	110	2,151	3,802	387	104	n.a.	668
Jobs created / jobs lost	High	Low–moderate	Moderate	Low	Very low	Low	Moderate
Migration trend (2013/20)	Positive	Negative	Slightly negative	Negative	Strongly negative	Negative	Positive
Existence of transition strategy	Yes	Yes	Yes	Yes	Yes (late)	Yes	Yes
Implementation effectiveness	High	Moderate	Moderate	Moderate	Low	Moderate	Moderate–high
Main transition focus	Innovation & R&D	Training & infrastructure	Infrastructure & transport	Environment & mobility	Social support	Clean energy	Clean energy & efficiency
Overall just transition outcome	Relatively successful	Mixed	Mixed	Mixed	Weak	Moderate	Relatively successful

Source: European Commission (Joint Research Centre), Eurostat databases, national and regional transition strategies, and authors' own elaboration.

The comparative indicators presented in Table 1 highlight substantial heterogeneity among European coal regions in terms of initial structural conditions, labour-market exposure, and transition trajectories. Although all analysed regions operate within a common European policy framework, the scale of employment losses, demographic trends, and institutional responses differs considerably.

The table illustrates that regions characterised by early strategic planning, strong administrative capacity, and diversified development priorities tend to achieve more favourable transition outcomes. Conversely, regions facing delayed policy responses, limited economic diversification, or persistent demographic decline encounter significantly greater challenges in translating financial support into sustainable socio-economic recovery (European Court of Auditors, 2022). These differences underline that the effectiveness of the just transition cannot be assessed solely through the volume of allocated funding, but must be analysed in relation to governance quality, stakeholder involvement, and the coherence between energy, labour-market, and regional development policies. The following subsections therefore examine individual regional trajectories in greater detail, with particular attention to the mechanisms that contributed to more or less successful transition outcomes.

5.1. Germany - Lusatia

Lusatia represents one of the most prominent coal regions in Germany and is historically divided between the federal states of Brandenburg and Saxony. The analysis presented here focuses on the Brandenburg part of Lusatia, which has undergone substantial structural change following the national decision to phase out coal-fired power generation by 2038.

Compared to other coal regions, Lusatia experienced a relatively limited reduction in coal-related employment between 2014 and 2020. Employment adjustments were primarily achieved through natural attrition and retirement rather than large-scale dismissals, which significantly reduced social tensions. During this period, net migration trends remained positive, indicating a comparatively stable demographic situation.

A defining feature of the Lusatian transition model has been the strong role of national financial support. The German federal government allocated approximately EUR 17 billion in structural assistance to coal regions, enabling early planning and long-term investment commitments. These resources were largely directed toward research and development, innovation infrastructure, digitalisation, and business development, with a particularly strong emphasis on strengthening regional innovation capacity.

However, the Lusatian case also illustrates the limitations of a transition strategy focused predominantly on socio-economic restructuring without a simultaneous acceleration of energy transformation. In the short term, coal production in remaining mines temporarily increased to compensate for regional energy deficits, which limited immediate reductions in carbon dioxide emissions. This highlights the distinction between socio-economic transition and energy transition, demonstrating that progress in one dimension does not automatically translate into environmental outcomes.

Overall, Lusatia can be considered an example of institutionally strong and financially well-supported transition, characterised by social stability but slower environmental transformation.

5.2. Poland – Małopolska and Silesia

Poland represents one of the most complex cases of coal transition within the European Union due to the scale of its coal sector and its continued reliance on domestic coal for energy security (EC, 2020). The regions of Małopolska and Silesia illustrate two different but interconnected transition pathways.

In Małopolska, a large number of workers participated in training and reskilling programmes between 2014 and 2020. Although participation rates were exceptionally high, the proportion of directly created jobs remained relatively limited. The region invested heavily in research, innovation, business development, and transport infrastructure, supported by both the European Regional Development Fund and the Cohesion Fund (Eurostat, 2024b).

Despite these efforts, net migration trends remained negative, suggesting that labour-market improvements were partially offset by outmigration. Furthermore, reductions in domestic coal production were partly compensated by increased coal imports, resulting in only modest environmental improvements and higher energy import dependency.

Silesia, by contrast, represents the largest coal region in the European Union in terms of employment and production volume (Eurostat, 2024a). Although coal-related employment declined significantly, overall unemployment rates decreased during the analysed period, supported by strong national labour demand and gradual workforce adjustment mechanisms. Public investments focused on transport infrastructure, environmental remediation, and energy-related projects, while the region demonstrated comparatively high effectiveness in job creation relative to the number of unemployed persons (EC, 2020).

Nevertheless, Silesia continues to face structural challenges, including limited capacity to fully replace coal-related employment through clean energy technologies and persistent environmental burdens. The Polish experience highlights the difficulty of achieving a rapid just transition in large-scale coal economies, particularly when national energy strategies continue to rely on fossil fuels

5.3. Czech Republic – Moravian-Silesian Region

The Moravian-Silesian Region represents one of the most industrialised areas in Central Europe and has experienced a pronounced decline in coal mining employment. Unlike regions where employment reduction occurred mainly through retirement, this region faced direct layoffs, increasing short-term labour-market pressures. The Czech government responded through the RE:START programme, designed to support economic diversification and improve regional competitiveness. Significant resources from European Structural and Investment Funds were allocated to environmental infrastructure, sustainable transport, and energy efficiency measures. As a result, the region achieved comparatively high energy savings, particularly in heat consumption. Despite these achievements, the environmental benefits of reduced coal production were partly offset by increased imports of fossil fuels, limiting emission reductions. Furthermore, while targeted retraining programmes demonstrated high individual employment success rates,

their overall coverage remained limited relative to the scale of employment losses. The Moravian-Silesian case underscores the importance of programme scale and timing. Effective instruments exist, but insufficient coverage may reduce their systemic impact (Eurostat, 2024b, EC, 2020, European Court of Auditors, 2022).

5.4. Romania – Jiu Valley

The Jiu Valley constitutes one of the most socio-economically vulnerable coal regions in the EU. Historically characterised by a high concentration of coal-mining employment, the region experienced severe labour-market disruption following the progressive closure of mining activities (Eurostat, 2024b). Employment losses were accompanied by long-term demographic decline and outward migration, further weakening regional development prospects. Public investment in the region initially focused predominantly on social, health, and educational infrastructure, reflecting urgent short-term stabilisation needs (EC, 2020). However, comparatively limited resources were directed toward innovation, entrepreneurship, and private-sector development, constraining long-term economic diversification. Evaluations of EU support mechanisms indicate that delays in strategy implementation and limited administrative capacity significantly reduced the effectiveness of transition instruments (European Court of Auditors, 2022). Only the most recent transition strategy, developed with broader stakeholder involvement, demonstrates stronger alignment with just transition principles.

A notable positive development has been the emergence of active civil society initiatives seeking to redefine regional identity and promote community-based development pathways (Interreg Europe, 2024). These bottom-up efforts illustrate the importance of participatory governance, particularly in regions where institutional capacity remains comparatively weak.

5.5. Spain – Asturias and León–Palencia

Spain implemented a relatively rapid coal phase-out, particularly after 2018, following national agreements on mining closures and restructuring (EC, 2020). In the regions of Asturias and León–Palencia, mine closures resulted in substantial job losses, which were initially addressed through income support schemes and early retirement arrangements. While these measures mitigated short-term social

disruption, they did not immediately generate sufficient long-term employment opportunities. Subsequent regional strategies shifted focus toward economic diversification, renewable energy deployment, and energy-efficiency investments. Asturias, in particular, increased investments in renewable energy infrastructure and achieved a comparatively higher proportion of job creation relative to coal employment losses (Eurostat, 2024b; 2024c). Nevertheless, structural labour-market rigidities and demographic challenges continued to constrain employment absorption capacity. This suggests that compensation-based approaches, although essential for social stability, must be complemented by active development policies capable of fostering sustainable private-sector growth (OECD, 2021). Overall, the Spanish case illustrates a transition pathway in which strong social protection mechanisms were gradually complemented by forward-looking investment strategies, resulting in moderate but comparatively stable transition outcomes..

5.6. Slovakia – Upper Nitra

Upper Nitra represents a coal region in which energy security considerations played a decisive role in shaping the transition pathway. The coal mine and associated power plant historically formed a significant component of regional electricity supply and district heating systems (EC, 2020). Although coal-mining employment declined steadily between 2014 and 2020, relatively few workers were expected to face abrupt unemployment due to the ageing workforce structure and decreasing interest in mining occupations among younger cohorts (Eurostat, 2024b). This gradual workforce adjustment reduced immediate labour-market pressures compared to regions experiencing sudden mine closures. At the same time, the planned closure of coal operations raised concerns regarding electricity supply stability and price volatility, highlighting the interaction between energy policy and regional development objectives. Substantial state aid supported investment projects in manufacturing and services, contributing to job creation beyond the coal sector.

Nevertheless, persistent skills mismatches and limited diversification capacity continue to pose structural challenges. As in other coal regions, the effectiveness of transition measures depends not only on financial support but also on alignment between retraining programmes and actual labour-market demand. The Upper Nitra case demonstrates the complexity of transitions in regions where employment, energy security, and territorial development objectives intersect.

Interim Analytical Insight

The comparative analysis reveals several cross-cutting patterns across the examined coal regions. First, early strategic planning and strong institutional capacity significantly reduce the intensity of social and labour-market disruption. Regions that initiated transition processes proactively and established clear governance structures demonstrated greater socio-economic stability and smoother workforce adjustment.

Second, the volume of allocated financial resources alone does not determine transition success. Although substantial EU and national funding has been directed toward coal regions, the effectiveness of these resources depends on administrative capacity, policy coordination, and the strategic alignment of investments with long-term development objectives (European Court of Auditors, 2022).

Third, labour-market instruments must be implemented at sufficient scale and in close connection with regional economic strategies. High participation rates in retraining programmes do not automatically translate into sustainable employment outcomes unless accompanied by credible job-creation pathways.

Fourth, reductions in domestic coal production do not necessarily result in proportional emission reductions when energy demand is substituted by fossil fuel imports. This finding reinforces the conceptual distinction between socio-economic transition and energy transition developed in Section 2.

Finally, stakeholder engagement and community involvement emerge as important determinants of transition legitimacy. Regions characterised by inclusive governance arrangements and active civil society participation tend to demonstrate higher levels of social acceptance and policy continuity. These cross-regional insights provide the analytical foundation for the synthesis of good practices and typological classification developed in the following section.

6 Synthesis of Good Practices and Key Lessons

The comparative analysis of European coal regions demonstrates that just transition processes are not determined by a single policy instrument or funding mechanism, but rather by a complex interaction between economic structures, institutional

capacity, governance arrangements, and strategic policy design. Although the analysed regions operate within a common European framework defined by the EGD and the JTM, their transition trajectories differ substantially, reflecting diverse historical legacies and regional development conditions. The empirical evidence summarised in Table 1 confirms that the initial structural position of coal regions significantly influences transition outcomes. Regions characterised by high employment concentration in coal mining and limited economic diversification faced more pronounced adjustment pressures, while regions with a broader industrial base exhibited greater adaptive capacity. These structural differences underline the importance of recognising heterogeneity among coal regions when designing transition strategies. *A first key lesson* concerns the importance of early and strategic planning. Regions that initiated transition strategies prior to large-scale mine closures demonstrated greater socio-economic resilience. Early planning facilitated gradual labour-market adjustment, reduced the intensity of employment shocks, and enabled the preparation of investment pipelines aligned with emerging sectors. Conversely, delayed policy responses frequently resulted in reactive strategies dominated by short-term compensation measures, which mitigated immediate social tensions but failed to generate sustainable development dynamics.

Closely related to timing is the role of institutional capacity and governance quality. Regions exhibiting strong coordination between national, regional, and local authorities achieved more effective implementation of transition measures. Stable administrative structures, clearly defined responsibilities, and continuity of leadership enhanced the absorption of European funds and improved policy coherence. In contrast, regions characterised by fragmented governance or limited administrative capacity encountered significant implementation delays, despite comparable levels of financial support. This confirms that governance quality constitutes a decisive determinant of just transition success.

Another central good practice emerging from the analysis is the diversification of regional economic structures. Regions that directed investments toward innovation, research infrastructure, clean energy technologies, and entrepreneurship demonstrated stronger long-term competitiveness. Empirical comparisons suggest that knowledge-based activities and support for small and medium-sized enterprises tend to generate more sustainable employment effects than infrastructure

investments alone. Diversification reduces vulnerability to sector-specific shocks and enhances the resilience of regional economies in the post-coal period.

Labour-market policies represent a further critical dimension of transition effectiveness. Although retraining and reskilling programmes are widely implemented across coal regions, their outcomes vary considerably. Comparative evidence indicates that high participation rates in training programmes do not automatically translate into employment creation. More favourable outcomes were observed in regions where training was closely aligned with regional investment strategies, involved employers in programme design, and was complemented by career guidance and job-matching services. Conversely, fragmented training initiatives produced limited systemic effects.

The analysis also highlights the need to balance social protection with active development measures. Income support schemes, early retirement, and compensation mechanisms play an essential role in preserving social stability during periods of structural change. However, regions that relied predominantly on passive measures exhibited weaker long-term development trajectories. More successful transition models gradually shifted from compensation-oriented approaches toward investment-driven development strategies that stimulate endogenous growth.

An additional lesson concerns the distinction between socio-economic transition and energy transition. The comparative cases demonstrate that reductions in domestic coal production do not automatically lead to proportional emission reductions, particularly when energy demand is substituted by imported fossil fuels. This underscores the necessity of integrated transition strategies that align labour-market policies, regional development objectives, and energy-system transformation. Investments in renewable energy and energy efficiency yield the greatest benefits when embedded within broader regional restructuring frameworks.

Stakeholder engagement and social dialogue emerge as critical success factors across all analysed regions. Inclusive governance arrangements involving trade unions, employers, municipalities, civil society organisations, and local communities enhance the legitimacy of transition processes and reduce resistance to structural change. In regions with strong mining identities, participatory approaches were particularly

important for rebuilding trust and facilitating acceptance of long-term transformation strategies.

Furthermore, the findings confirm the relevance of place-based approaches. Uniform policy solutions are insufficient to address the diverse challenges faced by coal regions, which differ in demographic trends, labour-market structures, and development potential. Tailored interventions reflecting regional characteristics and comparative advantages are more likely to produce durable outcomes, supporting the EU emphasis on Territorial Just Transition Plans. From a financial perspective, the synthesis demonstrates that the availability of funding alone does not guarantee successful transition outcomes. While European instruments such as the JTF, Invest-EU and cohesion policy resources play a crucial catalytic role, their effectiveness depends on the mobilisation of complementary national funding and private investment. Regions combining European support with long-term national commitment achieved more stable and predictable transformation paths.

To enhance comparative interpretation, a simple Just Transition Performance Index (JTPI) was developed as a synthetic analytical instrument. The index aggregates four core dimensions identified in the analysis—governance capacity, labour-market outcomes, economic diversification, and demographic trends—each reflecting key determinants of transition performance. The JTPI does not constitute a statistically weighted composite indicator. Rather, it serves as an interpretative framework that facilitates structured cross-regional comparison and supports the identification of broader transition patterns. The conceptual structure of the index is presented in Table 2.

Table 2: Structure of the Just Transition Performance Index (JTPI)

Dimension	Description
Governance capacity	Institutional coordination, implementation effectiveness, strategic planning
Labour-market outcomes	Employment adjustment, retraining effectiveness, job creation
Economic diversification	Investment structure, innovation, SME development
Demographic trends	Migration balance, population stability

Source: Own

Each dimension is assessed using a qualitative three-level scale, where 1 indicates low performance, 2 moderate performance, and 3 high performance. The index does not represent a statistically weighted composite measure, but serves as an interpretative framework supporting cross-regional comparison. Based on this framework, a qualitative JTPI score was calculated for each analysed region. The illustrative results are presented in Table 3.

Table 3: Illustrative Just Transition Performance Index (JTPI) by region

Region	Governance	Labour market	Diversification	Demography	JTPI (average)
Lusatia (DE)	3	3	3	2	2.75
Asturias (ES)	3	2	3	2	2.50
Silesia (PL)	2	2	2	2	2.00
Moravian-Silesian (CZ)	2	2	2	1	1.75
Jiu Valley (RO)	1	1	1	1	1.00

Note: The index represents a qualitative synthesis based on comparative indicators and expert assessment rather than a statistically weighted composite measure.

The index-based comparison reinforces the empirical patterns observed in Table 1 and facilitates the identification of distinct transition trajectories across coal regions. On the basis of the comparative analysis and JTPI results, coal regions can be grouped into three broad transition types.

Type I: Early planners and structurally resilient regions: These regions are characterised by early strategic planning, strong governance capacity, and diversified economic structures. Their transition trajectories exhibit relatively favourable labour-market outcomes and higher socio-economic resilience. Examples include Lusatia and Asturias.

Type II: Transitional regions with mixed outcomes: This group includes regions with partial diversification, improving but still constrained institutional capacity, and moderate labour-market adjustment. Transition progress is evident, yet remains uneven and sensitive to policy coordination. Examples include Silesia and the Moravian-Silesian Region.

Type III: Socially vulnerable transition regions: These regions display weak institutional capacity, high historical dependence on coal, and persistent adverse demographic trends. Transition processes are slower and more fragile, requiring sustained and targeted policy support. An illustrative case is the Jiu Valley. This typology highlights the necessity of differentiated, place-based policy responses and confirms that coal regions do not follow uniform transition pathways.

7 Implications for Coal Regions Currently in Transition

The findings of the comparative analysis presented in this chapter provide several important implications for coal-dependent regions that are currently entering or intensifying the transition process. As the EGD accelerates decarbonisation across Member States, an increasing number of regions face the complex challenge of simultaneously managing energy-system transformation, labour-market adjustment, and long-term regional development. The empirical evidence derived from the analysed coal regions offers valuable guidance for shaping effective and socially balanced transition strategies.

A first implication concerns the necessity of adopting a comprehensive and forward-looking transition vision. Regions that frame coal phase-out solely as an energy-sector issue risk underestimating its broader socio-economic consequences. In contrast, regions applying an integrated approach—linking energy policy with regional development strategies, labour-market planning, education systems, and innovation policy—demonstrate more coherent and resilient transition trajectories. Such integration reduces policy fragmentation and increases the likelihood that new economic activities will absorb displaced workers, thereby strengthening both social cohesion and long-term competitiveness.

Second, early institutional preparation is essential. Regions benefit from establishing dedicated governance structures responsible for coordinating transition-related investments and stakeholder engagement. Clear institutional leadership, stable administrative capacity, and well-defined responsibilities enhance the effective absorption of EU funding and reduce implementation delays (European Court of Auditors, 2022). Without such governance arrangements, even substantial financial allocations may fail to generate durable socio-economic transformation.

Third, labour-market implications require proactive and strategic planning. Concentrated employment shocks in coal regions cannot be absorbed through general labour-market dynamics alone. Regions achieving more favourable outcomes engaged in early workforce planning, systematic identification of skills gaps, and close cooperation with regional employers. Retraining initiatives proved most effective when aligned with concrete investment projects and realistic employment prospects, rather than implemented as isolated policy instruments. The credibility of transition strategies therefore depends heavily on the visibility of tangible job-creation pathways.

A further implication relates to economic diversification. Regions relying on a narrow set of alternative industries remain vulnerable to future economic shocks. The comparative analysis confirms that sustainable transition outcomes are more likely when diversification strategies are broad-based and supported by investments in innovation ecosystems, entrepreneurship, clean energy technologies, and small and medium-sized enterprises. Public investment should therefore aim not merely to replace lost coal-related employment but to enhance long-term regional adaptability and competitiveness. The analysis also highlights the critical role of social dialogue and stakeholder involvement. Regions currently undergoing transition benefit from inclusive governance models that actively involve workers, trade unions, municipalities, educational institutions, and civil society organisations. Participatory processes strengthen social trust, reduce resistance to structural change, and improve the quality of strategic decision-making. In regions with strong mining identities, stakeholder engagement plays a particularly important role in facilitating acceptance of long-term transformation beyond the coal legacy.

From a financial perspective, EU funds should be regarded as catalytic instruments rather than substitutes for national commitment. While mechanisms such as the JTF provide essential support, the scale of required investment exceeds EU allocations alone (EC, 2021). Regions demonstrating stable transition trajectories typically combined European resources with predictable national co-financing and long-term investment frameworks. Fiscal stability and policy continuity therefore remain indispensable preconditions for successful transformation. Transition strategies must ensure coherence between socio-economic objectives and energy-system transformation. Coal phase-out does not automatically produce proportional emission reductions if energy demand is replaced by other fossil fuels. Integrated

investment in renewable energy and low-carbon infrastructure generates the greatest benefits when embedded within broader regional development strategies.

Finally, the transition process entails significant temporal challenges. Social and employment-related costs tend to materialise rapidly, whereas the benefits of economic restructuring emerge gradually. Policymakers must therefore manage expectations, maintain long-term political commitment, and ensure transparent communication throughout the transition process. Continuous monitoring and adaptive governance mechanisms are essential for sustaining public support over time. Overall, the implications derived from this study emphasise that just transition is not a one-dimensional policy intervention but a long-term development process. Regions currently entering the transition phase face substantial risks, but also significant opportunities to modernise economic structures, improve environmental performance, and strengthen social cohesion.

8 Conclusions

The transition toward climate neutrality represents one of the most far-reaching structural transformations currently unfolding within the European Union. As demonstrated throughout this chapter, coal phase-out processes extend well beyond the energy sector and entail profound socio-economic implications for affected regions. The European Green Deal and the Just Transition Mechanism have established a comprehensive policy architecture designed to mitigate these impacts and align climate objectives with social and territorial cohesion. The comparative analysis of selected European coal regions confirms that transition outcomes are shaped by a complex interaction between initial structural conditions, governance capacity, labour-market dynamics, and the strategic orientation of public investment. Regions characterised by early planning, diversified economic structures, and strong institutional coordination demonstrate greater socio-economic resilience. Conversely, regions with delayed strategic responses, limited diversification, and weak administrative capacity face more persistent adjustment challenges. The development of the qualitative Just Transition Performance Index (JTPI) contributes to the analytical assessment of regional transition pathways by providing a structured framework for cross-regional comparison. While not intended as a statistically definitive ranking tool, the JTPI facilitates a systematic evaluation of governance performance, labour-market adjustment, economic diversification, and

demographic resilience. The resulting typology of transition regions underscores the necessity of differentiated, place-based policy approaches. The findings of this chapter highlight that financial support, although essential, is not sufficient to guarantee successful regional transformation. Institutional quality, policy coherence, and stakeholder engagement emerge as decisive determinants of long-term transition performance. Moreover, the distinction between socio-economic transition and energy-system transformation demonstrates that emission reductions and regional development objectives must be pursued in an integrated manner. Ultimately, the just transition should not be understood merely as a compensatory mechanism accompanying decarbonisation, but as a development strategy capable of fostering structural modernisation, innovation, and renewed regional competitiveness. As additional European regions enter advanced stages of coal phase-out, the lessons derived from early transition experiences provide valuable guidance for aligning climate ambition with social stability and territorial sustainability.

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THE IMPACT OF TELEVISION NEWS COVERAGE OF RISING AND FALLING PRICES ON FOOD, GAS, AND RENT PRICE CHANGE EXPECTATIONS IN THE UNITED STATES

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This paper examines whether and how television news coverage of rising and falling prices affects US households' expectations of food, gas, and rent price changes. Using vector autoregressions and data from June 2013 to October 2024, we find that a sudden and unexpected increase in television news coverage of rising prices on CNN and Fox News leads to a statistically significant decrease in food and gas price change expectations, while the impact on rent price change expectations is statistically insignificant. In contrast, increased television news coverage of falling prices has no statistically significant impact on commodity price change expectations. These findings have important policy implications, as they indicate that the impact of media coverage of rising and falling prices on price change expectations is limited to food and gas, and depends on the content of the news. One possible explanation is that increased media coverage of rising prices signals a tightening of monetary policy, prompting households to revise their short-term price change expectations. To this end, we use the GDELT Project to measure television news coverage, as well as vector autoregression and impulse response analysis.

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1 Introduction

In recent years, inflation has been a hot topic in the news media. Geopolitical events, such as the war in Ukraine (since 2014, with escalation in 2022), the war in Gaza (since 2023), and the war in Iran (since 2026), have increased the risk of inflation and fuelled speculation about its future level. These events have disrupted the production and transport of commodities, contributing to rising prices of goods such as food and gas, as observed in the past (Caldara et al., 2026; Yang et al., 2023; Zhou, 2025). The risk of inflation has also increased due to the tariff war (since 2025) (Dvorkin et al., 2025; Hacıoğlu-Hoke et al., 2026; Halbersleben et al., 2026; Hobijn & Nechio, 2025; Minton & Somale, 2025).

In 2020, following the outbreak of the COVID-19 epidemic in the United States, inflation began to make headlines in the news media (Macaulay & Song, 2023). Initially, the risk of deflation outweighed that of inflation (Christensen et al., 2020; Hajdini et al., 2025). However, as the economy recovered in 2021 and 2022, inflation soon began to show its teeth, putting pressure on the Federal Reserve to raise the policy rate (Blanchard & Bernanke, 2023; de Soyres et al., 2026; Lebow & Peneva, 2024). In 2022, inflation in the United States peaked at 8 per cent, the highest since the Great Inflation (Binder & Kamdar, 2022; Hajdini et al., 2025).

Research (Mehra & Herrington, 2008) shows that a sudden and unexpected increase in inflation raises inflation expectations. Evidence (Barrales-Ruiz et al., 2026; Moessner, 2024) also shows that a sudden and unexpected increase in inflation expectations raises inflation, suggesting that inflation and inflation expectations reinforce each other. In addition, inflation expectations affect the effectiveness of fiscal and monetary policy (D'Acunto et al., 2023; Weber et al., 2022). Therefore, the Federal Reserve should manage both. To achieve this, the central bank should monitor news on inflation, as media coverage of inflation affects households' expectations (Bauer, 2015; Binder et al., 2024, 2025; Chahrour et al., 2025; Pfajfar & Santoro, 2013; Kmetz et al., 2022; Larsen et al., 2021; Lei et al., 2015). To address a gap in the literature, this chapter examines whether and how television news coverage of rising and falling prices affects US households' expectations of food, gas, and rent price changes.

The novelty of this chapter lies in its focus on the impact of television news coverage of prices on US households' expectations of commodity price changes, distinguishing between news about rising prices and news about falling prices.

2 Literature review

Inflation expectations are a major concern for policymakers, as they influence the decisions of economic agents and, consequently, affect inflation and other macroeconomic outcomes (Weber et al., 2022; D'Acunto et al., 2023). The media is considered a primary source of news for households (Larsen et al., 2021; Binder et al., 2025) and therefore plays an important role in shaping inflation expectations and inflation dynamics. Central banks also acknowledge the relevance of media reporting in monetary policy strategy and inflation expectation management (see Assenmacher et al., 2021).

Recent research highlights the impact of media inflation reporting on household inflation expectations. Lamla and Lein (2014) model household inflation expectations and show that their accuracy (defined as the gap between actual inflation and expectations) depends on both the extent and tone of reporting. Using data from Germany, they find that increased reporting improves accuracy, whereas a negative tone reduces it. Binder et al. (2025) analyse daily inflation news coverage from three cable television news outlets and show that coverage increases on inflation data release days. The extent of coverage is positively related to inflation surprises (defined as actual inflation exceeding professional forecasts), with more coverage observed in response to positive than negative surprises. They further find that media inflation coverage shocks increase household inflation expectations in the short term (up to 10 days after the shock).

Chahrour et al. (2025) theoretically and empirically examine the asymmetric response of US households' inflation expectations to media inflation news, using the University of Michigan Survey of Consumers (UMSC). Their results show that only unfavourable news, such as reports of price increases, leads to higher inflation expectations. Larsen et al. (2021), using the Dow Jones Newswire archive and natural language processing techniques, identify key media topics relevant to US household inflation expectations and realised inflation, including education, trading, health, internet, the White House, and transactions. They also demonstrate that the weight

households assign to news changes over time, with the strongest information rigidities observed during the Great Recession, while increased media coverage reduces these rigidities.

Kmetz et al. (2022) document that the gap between inflation expectations of professional forecasters and households in the United States widened after the pandemic, attributing this to increased coverage and a more negative tone in inflation-related media reporting. Bolliger (2025) studies Swiss households and analyses inflation reporting in Swiss newspapers. He constructs a news measure based on the difference between positive and negative mentions of inflation (increases versus decreases) and finds that higher news intensity is associated with higher inflation expectations, particularly during periods of rising inflation and especially in the German-speaking part of Switzerland. He also finds that newspapers tend to assign similar weight to reports of inflation increases and decreases.

Xu et al. (2018) develop a theoretical model showing how both the quantity and bias of media inflation reporting affect inflation expectations, with bias exerting a stronger influence than reporting volume. Their model is empirically validated using Chinese data. Xu et al. (2024) further examine the role of television news in China and, using time-varying Granger causality tests, show that media inflation coverage can predict inflation expectations; however, inflation expectations also Granger-cause television inflation reporting in certain periods.

3 Methodology

3.1 Vector autoregression model specification

The empirical approach involves estimating a reduced-form vector autoregression (VAR) model and orthogonalized impulse response functions (OIRFs). The study distinguishes three types of commodity price change expectations; accordingly, three groups of VAR models were estimated to analyse the impact of television news coverage of rising and falling prices on food, gas, and rent price change expectations. The analysis further differentiates the effects of coverage of rising and falling prices. Thus, altogether six VAR models were estimated for each television network. The

study focuses on two television channels, CNN and Fox News, resulting in a total of twelve VAR models.

The optimal lag length was determined using the Hannan–Quinn information criterion (HQIC). According to this criterion, two lags were selected as optimal for all estimated VAR models (see Appendix). The stability of the VAR models was also assessed; the corresponding eigenvalues indicate that all models are stable (see Appendix).

The study covers the period from June 2013 to October 2024. The VAR models include the following variables: median one-year-ahead inflation uncertainty (infunc), commodity price change expectations, the natural logarithm of the industrial production index (ln_ip), the unemployment rate (ur), the first difference of the natural logarithm of the consumer price index (dln_cpi), television news coverage of rising and falling prices, and the federal funds effective rate (ffer). Food, gas, and rent price change expectations are included separately in the VAR specifications.

Television news coverage variables are specified separately, including coverage of rising prices by CNN (cnn_up) and Fox News (fox_up), as well as coverage of falling prices by CNN (cnn_down) and Fox News (fox_down). The variables are ordered in the VAR models as listed above. This ordering follows established empirical practice, with inflation uncertainty and inflation expectations placed first, followed by standard macroeconomic variables used to identify shocks (Bassett et al., 2014; Baker et al., 2016). Structural shocks are identified using a Cholesky decomposition of the covariance matrix of the reduced-form residuals. Table 1 provides detailed descriptions of all variables used in the analysis.

Table 1: Variable descriptions

Variable	Description	Source
infunc	Difference between the 90th and 10th percentiles of the redistribution of inflation-at-risk	Federal Reserve Bank of New York (2025a)
food	Food price change expectations, median one-year ahead point prediction	Federal Reserve Bank of New York (2025b)
gas	Gas price change expectations, median one-year ahead point prediction	Federal Reserve Bank of New York (2025c)

Variable	Description	Source
rent	Rent price change expectations, median one-year ahead point prediction	Federal Reserve Bank of New York (2025d)
ln_ip	Industrial Production: Total Index, index 2017 = 100, monthly, not seasonally adjusted	Board of Governors of the Federal Reserve System (2025a)
ur	Unemployment rate, percent, monthly, seasonally adjusted	U.S. Bureau of Labor Statistics (2025a)
dln_cpi	Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, index 1982–1984 = 100, monthly, seasonally adjusted	U.S. Bureau of Labor Statistics (2025b)
cnn_up	(price OR prices) AND (climb OR climbed OR climbs OR climbing OR grow OR grew OR grown OR grows OR growing OR increase OR increased OR increases OR increasing OR jump OR jumped OR jumps OR jumping OR rise OR rose OR risen OR rises OR rising OR soar OR soared OR soars OR soaring OR spike OR spiked OR spikes OR spiking OR surge OR surged OR surges OR surging) AND (Station:CNN)	GDELT Project (2025)
cnn_down	(price OR prices) AND (decline OR declined OR declines OR declining OR decrease OR decreased OR decreases OR decreasing OR drop OR dropped OR drops OR dropping OR fall OR fell OR fallen OR falls OR falling OR plunge OR plunged OR plunges OR plunging OR reduce OR reduced OR reduces OR reducing OR shrink OR shrank OR shrunk OR shrinks OR shrinking OR sink OR sank OR sunk OR sinks OR sinking OR slide OR slid OR slides OR sliding OR slump OR slumped OR slumps OR slumping) AND (Station:CNN)	GDELT Project (2025)
fox_up	(price OR prices) AND (climb OR climbed OR climbs OR climbing OR grow OR grew OR grown OR grows OR growing OR increase OR increased OR increases OR increasing OR jump OR jumped OR jumps OR jumping OR rise OR rose OR risen OR rises OR rising OR soar OR soared OR soars OR soaring OR spike OR spiked OR spikes OR spiking OR surge OR surged OR surges OR surging) AND (Station:FOXNEWS)	GDELT Project (2025)
fox_down	(price OR prices) AND (decline OR declined OR declines OR declining OR decrease OR decreased OR decreases OR decreasing OR drop OR dropped OR drops OR dropping OR fall OR fell OR fallen OR falls OR falling OR plunge OR plunged OR plunges OR plunging OR reduce OR reduced OR reduces OR reducing OR shrink OR shrank OR shrunk OR shrinks OR shrinking OR sink OR sank OR sunk OR sinks OR sinking OR slide OR slid OR slides OR sliding OR slump OR slumped OR slumps OR slumping) AND (Station:FOXNEWS)	GDELT Project (2025)

Variable	Description	Source
	shrinks OR shrinking OR sink OR sank OR sunk OR sinks OR sinking OR slide OR slid OR slides OR sliding OR slump OR slumped OR slumps OR slumping) AND (Station:FOXNEWS)	
ffer	Federal Funds Effective Rate, per cent, monthly, not seasonally adjusted	Board of Governors of the Federal Reserve System (2025b)

3.2 Operationalising lexical variables for directionality in price movement

For our analysis, we operationalised two groups of lexical variables: *cnn_up* and *fox_up* for Television news coverage of upward price movement (Group 1), and *cnn_down* and *fox_down* for Television news coverage of downward price movement (Group 2), using the GDELT Project (2025). Group 1 comprises upward movement verbs, and Group 2 comprises downward movement verbs. The verbs were selected as the unit of analysis, alongside the nouns *price* and *prices*, because they linguistically express changes and the direction of these changes.

Group 1 comprised verbs expressing upward movement, i.e. *climb*, *grow*, *increase*, *jump*, *rise*, *soar*, *spike*, and *surge* in all possible forms (i.e. climb OR climbed OR climbs OR climbing OR grow OR grew OR grown OR grows OR growing OR increase OR increased OR increases OR increasing OR jump OR jumped OR jumps OR jumping OR rise OR rose OR risen OR rises OR rising OR soar OR soared OR soars OR soaring OR spike OR spiked OR spikes OR spiking OR surge OR surged OR surges OR surging).

Regarding their meaning, we can rank these verbs according to their intensity as follows:

(1) verbs expressing general, mild or moderate upward movement, i.e. *increase*, *grow*, *rise* and *climb*. This group consists of verbs which denote a somewhat neutral upward quantitative change of a given phenomenon. That is, *increase* and *rise* are the most neutral verbs for describing upward movement (e.g. in amount, number, value), without implying the intensity or rate. The verbs *grow* and *climb* both suggest gradual, steady and sustained (organic) progressive development over a given period of time (e.g. of prices, costs, inflation).

(2) verbs expressing strong or sharp upward movement, i.e. *jump* and *surge*. Both these verbs describe significant and sudden upward change, which is stronger than moderate, where *jump* points to a distinct and somewhat abrupt and noticeable upward movement, and *surge* shows intensity by implying force, momentum, dynamic acceleration (e.g. after a period of stability or slow growth).

(3) verbs expressing severe or dramatic upward movement, i.e. *spike* and *soar*. While both verbs denote the highest degree of intensity of upward change, *spike* is typically used for describing a sharp and short-lived or unstable peak in something (e.g. oil prices, gas prices, interest rates); on the other hand, *soar* stresses a more sustained and expansive rise to very high levels rather than a temporary phenomenon.

Group 2 comprised verbs expressing downward movement, i.e. *decline*, *decrease*, *drop*, *fall*, *plunge*, *reduce*, *shrink*, *sink*, *slide*, and *slump* in all possible forms (i.e. decline OR declined OR declines OR declining OR decrease OR decreased OR decreases OR decreasing OR drop OR dropped OR drops OR dropping OR fall OR fell OR fallen OR falls OR falling OR plunge OR plunged OR plunges OR plunging OR reduce OR reduced OR reduces OR reducing OR shrink OR shrank OR shrunk OR shrinks OR shrinking OR sink OR sank OR sunk OR sinks OR sinking OR slide OR slid OR slides OR sliding OR slump OR slumped OR slumps OR slumping).

Regarding their meaning, we can rank these verbs according to their intensity as follows:

(1) verbs expressing general (neutral), mild or moderate downward movement, i.e. *decrease*, *reduce*, *decline*, *fall*, *drop*, *sink*, and *slide*. These verbs thus express downward quantitative change (e.g. of size, amount, level, degree of something). Specifically, *decrease* and *fall* are rather neutral, descriptive verbs used to denote a gradual and non-evaluative downward movement, whereas *reduce* somehow implies a deliberate action (e.g. 'A company has reduced its prices'). All other verbs in this category describe a moderate downward movement, with slight differences in meaning. *Drop* points to a more sudden movement, whereas *decline* shows a gradual weakening or deterioration over time. On the other hand, *sink* suggests a slower and steadier movement to a lower level (e.g. of prices, profits, shares), while *slide* suggests a gradual and longer worsening or lowering of a given phenomenon. Both of these verbs carry a rather negative evaluative tone.

(2) verbs expressing strong or sharp downward movement, i.e. *shrink* and *slump*. Both verbs are used to discuss a more pronounced downward movement related to a given phenomenon. Specifically, *shrink* means a noticeable reduction (e.g. in size, extent, scale) that unfolds progressively, while *slump* expresses a sudden and substantial downturn (e.g. in economic activity).

(3) verbs expressing a severe or dramatic downward movement, i.e. *plunge* and *plummet*. These two verbs are associated with the highest degree of downward movement (as regards intensity) as they both express a sudden and steep decline, with *plummet* expressing an extreme, almost vertical fall, which is uncontrolled and dramatic.

4 Results

This section presents the results of the OIRF analyses. We examine the responses of the variables included in the VAR models to a sudden and unexpected increase in television news coverage of both rising and falling prices. The analysis incorporates three types of commodity price change expectations, allowing us to distinguish between the effects of shocks to coverage of rising and falling prices. We also differentiate between television news coverage from two networks, CNN and Fox News. In total, twelve VAR models are analysed.

In the reported OIRFs, the left-hand panels show the responses of each variable to a shock in television news coverage of rising prices by CNN and Fox News, while the right-hand panels show the responses to a shock in coverage of falling prices. In each panel, we combine two OIRFs: one for CNN and one for FOX News.

4.1 Food prices

Firstly, we analyse a set of OIRFs that include food prices in the variable specification. Figure 1 shows the responses to a one-standard-deviation shock in television news coverage of rising or falling prices over a 60-month horizon, with 68% confidence intervals.

A shock to television news coverage of rising prices leads to a negative response in the CPI growth; however, the impact is initially insignificant and becomes significant in the medium term. In contrast, a shock to coverage of falling prices produces a significant negative response in the CPI growth, which dissipates quickly and becomes insignificant in the medium term.

Shocks to television news coverage of both rising and falling prices lead to a significant increase in the federal funds effective rate. The impact dissipates more quickly after shocks to coverage of rising prices than after shocks to coverage of falling prices.

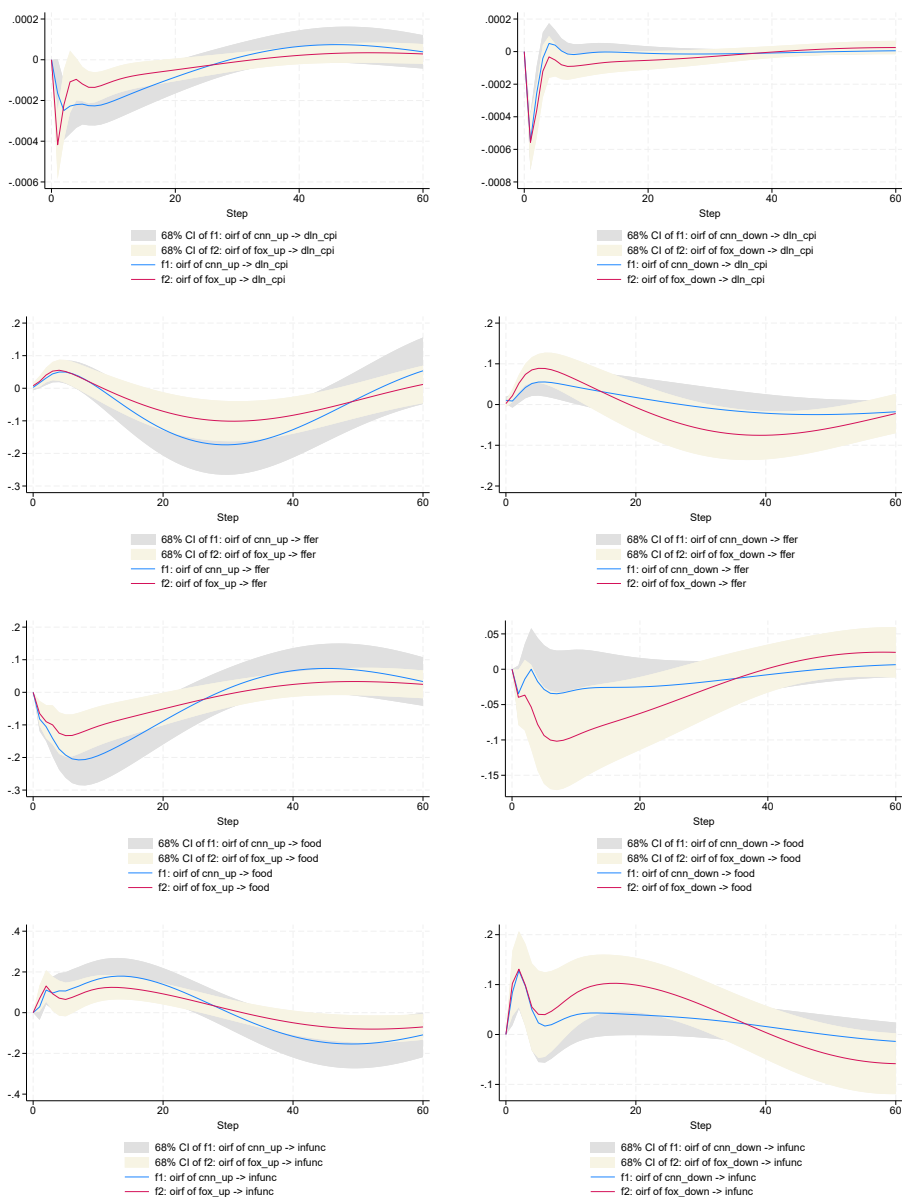
The OIRFs indicate that food price change expectations respond differently to coverage of rising and falling prices. A shock to coverage of rising prices has a negative and statistically significant impact in both the short and medium term. In contrast, a shock to coverage of falling prices has no statistically significant impact.

A shock to television news coverage of rising prices produces a positive response in inflation uncertainty, which is initially insignificant but becomes significant in the medium term. Conversely, a shock to coverage of falling prices leads to a significant negative response in inflation uncertainty, but only in the short term.

The response of industrial production to shocks in television news coverage is mixed. A shock to coverage of rising prices leads to an initially insignificant negative response, which becomes significant in the medium term. Similarly, a shock to coverage of falling prices causes an initially insignificant negative response, followed by a brief significant decline, with significance re-emerging in the medium term.

Increased television news coverage of both rising and falling prices has insignificant effects on the unemployment rate in the short term. However, a shock to coverage of rising prices leads to a significant positive response in unemployment in the medium term, while the response to coverage of falling prices remains insignificant.

An increase in television news coverage of rising and falling prices leads to a significant increase in inflation reporting, which dissipates in the short term.



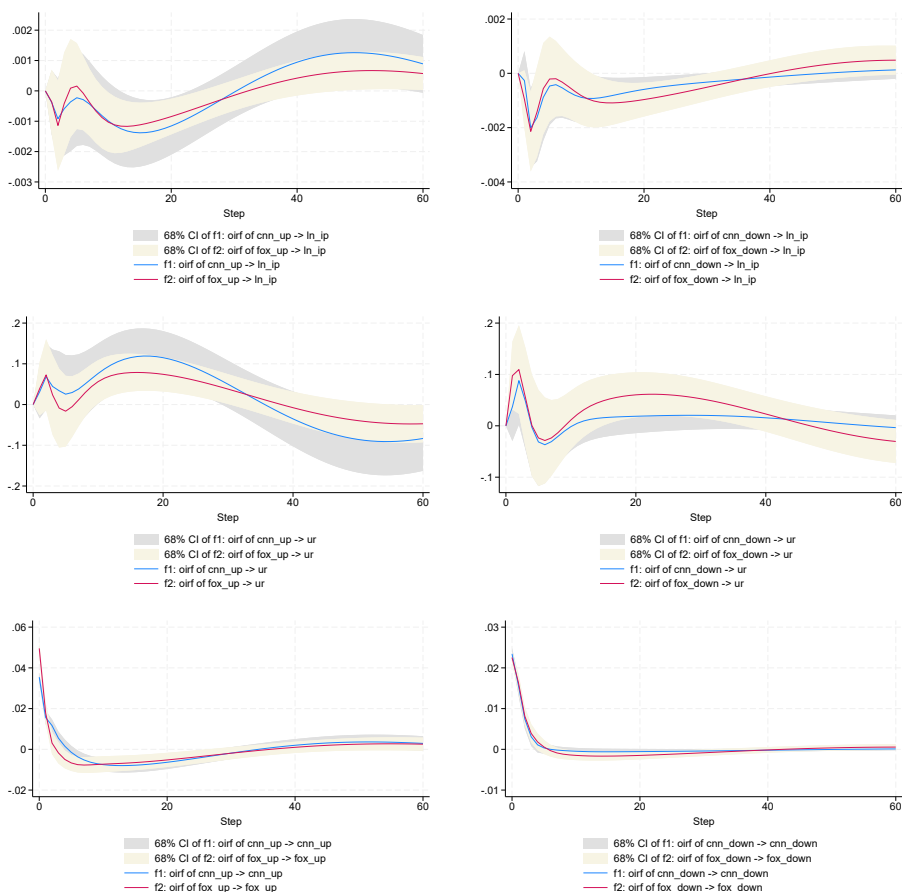


Figure 1: OIRFs for food prices

Source: own.

4.2 Gas prices

Secondly, we revise the specification of variables in the VAR models by replacing food prices with gas prices. Figure 2 presents the second set of OIRFs, illustrating the responses to a one-standard-deviation shock in television news coverage of rising or falling prices over a 60-month horizon, with 68% confidence intervals.

A shock to television news coverage of rising prices has an indeterminate and insignificant impact on CPI growth. In contrast, a shock to coverage of falling prices

leads to a negative and significant response in CPI growth immediately after the shock. This response is short-lived, as it is followed by a brief positive and significant impact on CPI in the medium term.

A shock to television news coverage of rising or falling prices leads to an increase in the federal funds effective rate. The initial response is insignificant in both cases but becomes significant in the short and medium term, with slight differences in magnitude and persistence between the two shocks.

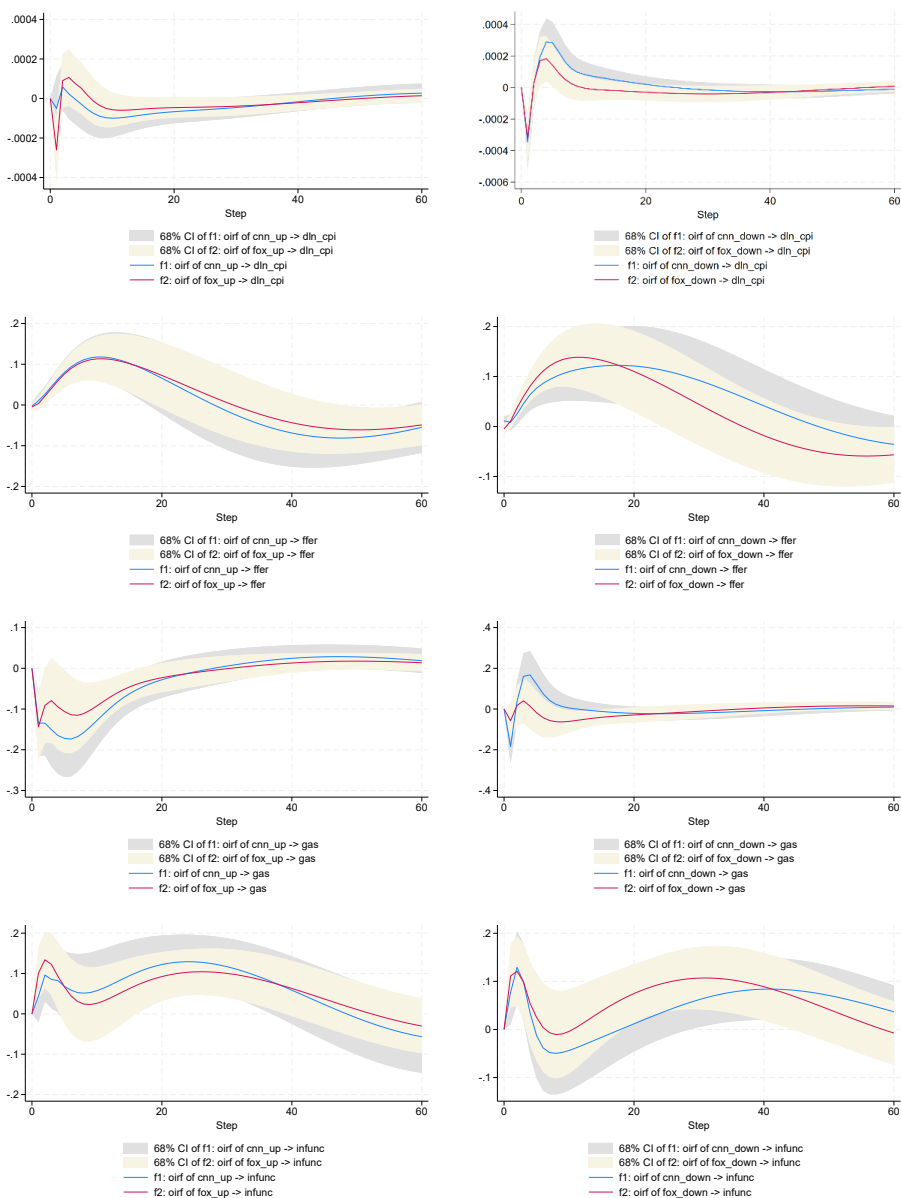
A shock to television news coverage of rising prices produces an immediate, negative, and significant response in gas price change expectations; however, this impact becomes insignificant shortly after the shock. Negative effects reappear in the medium term. In contrast, a shock to coverage of falling prices has an indeterminate and insignificant impact on gas price change expectations.

The OIRFs show that inflation uncertainty increases in response to shocks in television news coverage of both rising and falling prices. In both cases, the response is significant in the short term, with minor differences in magnitude and persistence before dissipating. A shock to coverage of falling prices produces a slightly stronger response than a shock to coverage of rising prices. Additionally, a shock to coverage of rising prices leads to a significant increase in inflation uncertainty in the medium term.

Industrial production decreases in response to shocks in television news coverage of rising and falling prices. These responses are initially insignificant but become significant for a brief period in the short term. In the medium term, small but significant negative impacts persist following both types of shocks.

A shock to television news coverage of rising and falling prices leads to an increase in the unemployment rate. The initial response is insignificant, but it becomes significant for a brief period in the short term. A shock to coverage of rising prices also produces a significant positive effect on unemployment in the medium to long term, whereas the response to coverage of falling prices remains insignificant.

Finally, a shock to television news coverage of rising and falling prices leads to a significant short-term increase in overall price-related news coverage. This response is immediate and dissipates rapidly.



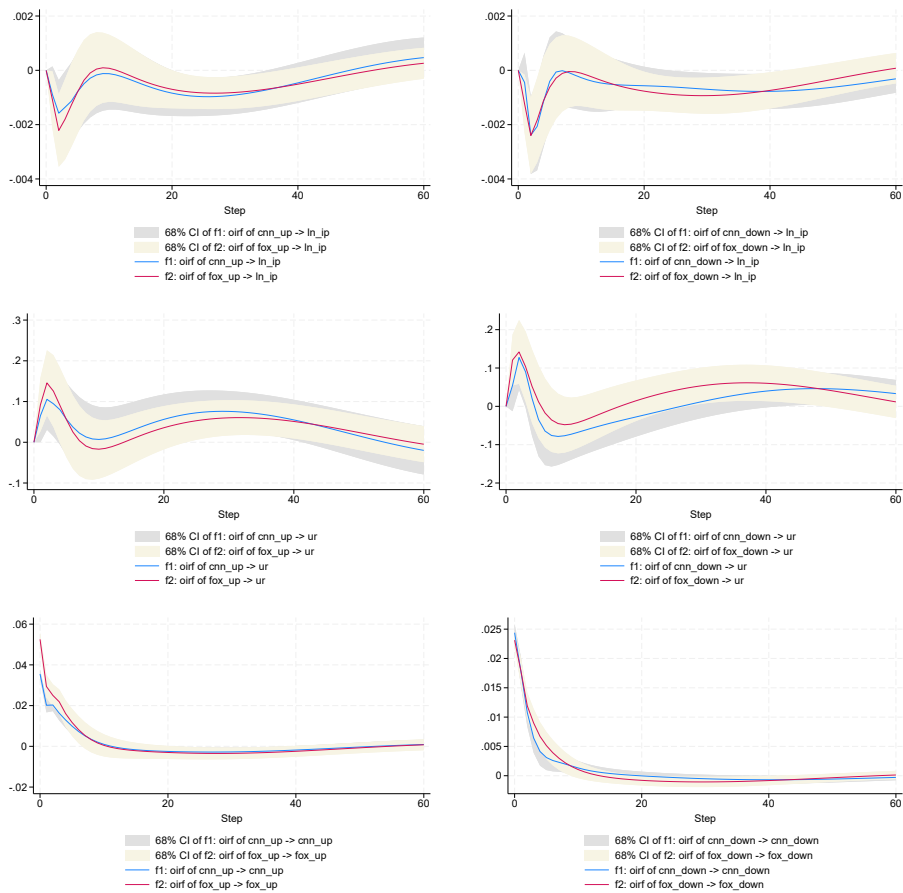


Figure 2: OIRFs for gas prices

Source: own.

4.3 Rent prices

Lastly, we analyse the set of VAR models in which rent prices are included as the commodity price change expectation variable. Figure 3 presents the OIRFs for shocks to television news coverage of rising and falling prices. We apply a one-standard-deviation shock and observe the responses of the variables in the VAR models over a 60-month horizon, with 68% confidence intervals.

A shock to television news coverage of rising prices has a negative impact on CPI growth; however, this impact is insignificant in the short term and remains insignificant throughout the horizon. By contrast, a shock to coverage of falling prices leads to a significant negative impact on CPI growth on impact, which dissipates shortly after the shock.

A shock to television news coverage of both rising and falling prices has a positive impact on the federal funds effective rate in the short term. The response is initially insignificant, becomes significant over the remainder of the short-term horizon, and then dissipates.

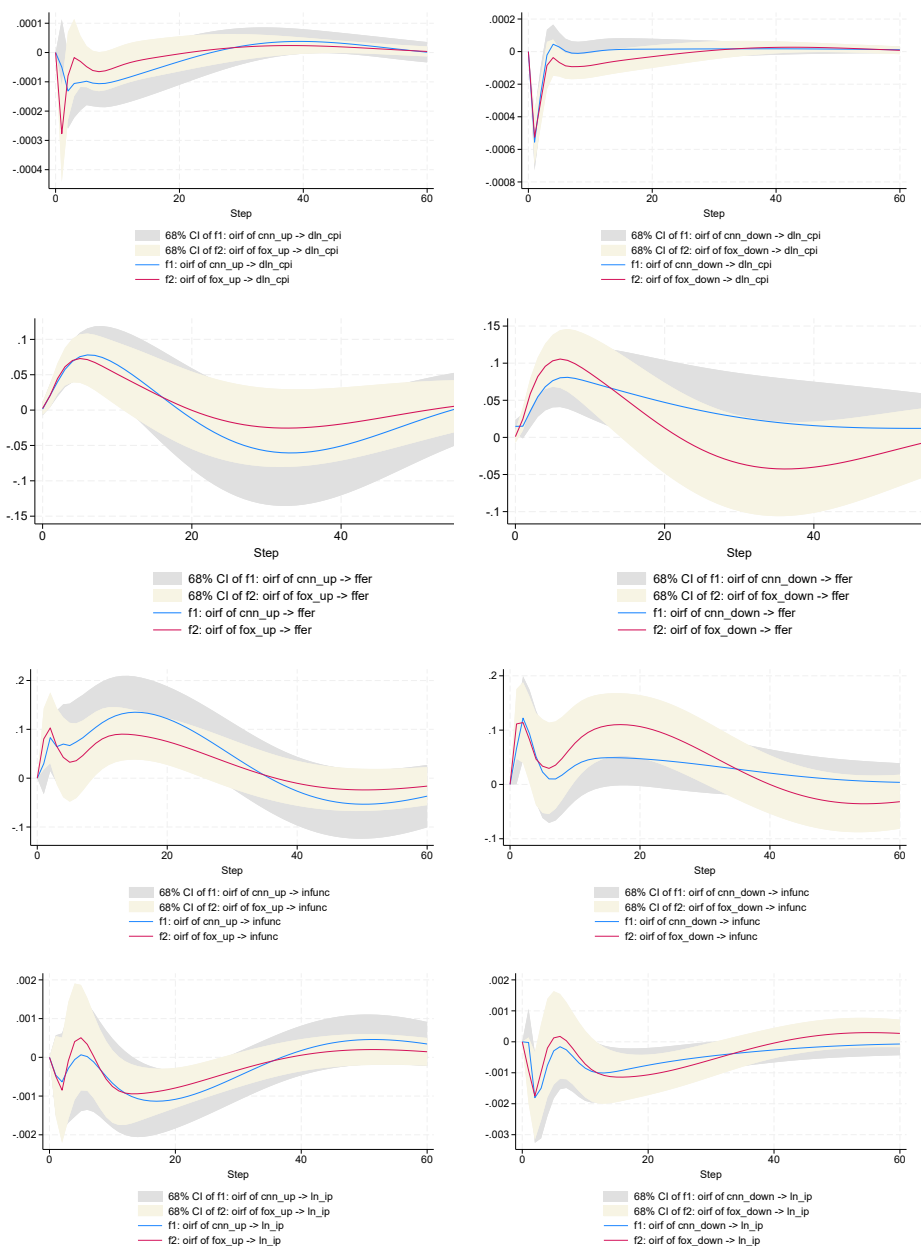
Inflation uncertainty responds differently to shocks in television news coverage of rising and falling prices. A shock to coverage of rising prices has a positive impact on inflation uncertainty, which is significant only in the medium term. In contrast, a shock to coverage of falling prices produces a positive and significant impact on inflation uncertainty in the short term.

Shocks to television news coverage of both rising and falling prices have a negative and significant impact on industrial production in the medium term. Although the responses are similar for both types of coverage, they differ slightly in magnitude and persistence.

As shown in Figure 3, a shock to television news coverage of rising and falling prices has an indeterminate and insignificant impact on rent price change expectations.

The unemployment rate rises in response to a shock in television news coverage of rising prices; however, this impact is only significant in the medium term. In contrast, a shock to coverage of falling prices has an indeterminate and insignificant impact on the unemployment rate.

Finally, a shock to television news coverage of both rising and falling prices has a positive and significant impact on the coverage variable itself in the short term.



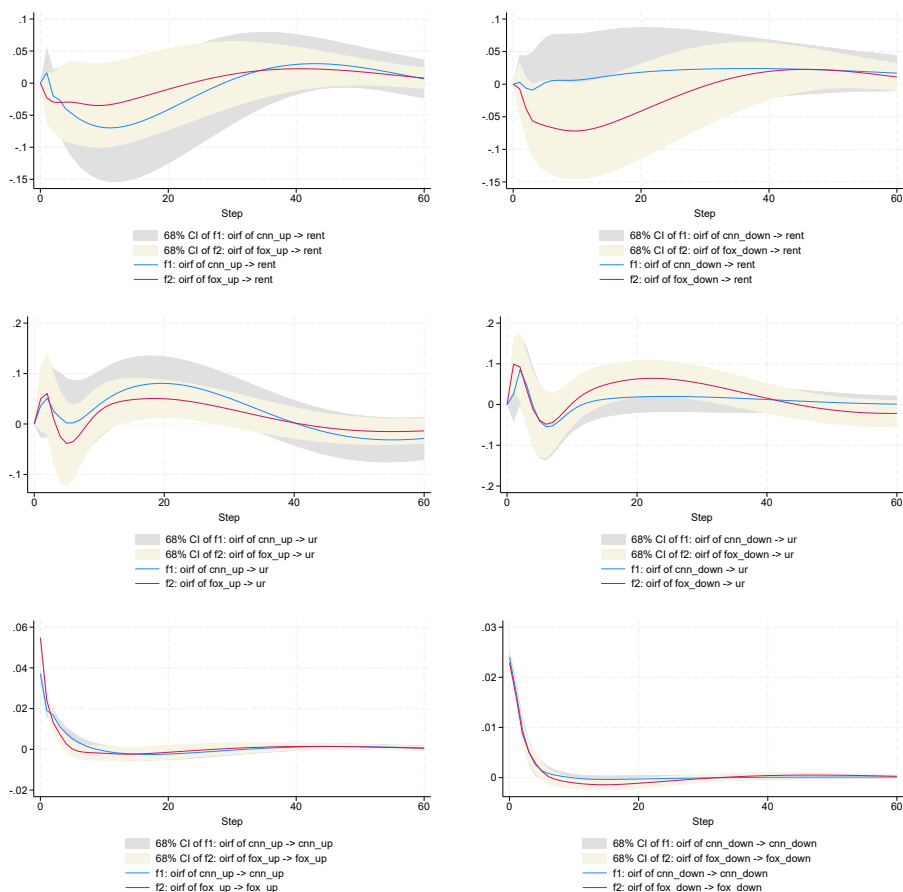


Figure 3: OIRFs for rent prices

Source: own.

5 Discussion

In this chapter, we discuss the responses of each variable included in the analysis to an increase in television news coverage of rising and falling prices.

5.1 CPI

The responses of CPI growth to shocks from Television news reporting on rising and falling prices can be distinguished by their magnitude and persistence. Across the specifications, increased coverage of rising prices has an insignificant impact on

CPI growth initially, with significant negative effects emerging in the medium term. In contrast, coverage of falling prices produces a significant negative impact on CPI in the short term.

Figure 2 shows that CPI growth responds differently to shocks in television news coverage of rising and falling prices. A shock to coverage of rising prices has an insignificant impact on CPI growth throughout the short horizon. By contrast, CPI growth responds negatively and significantly to a shock in coverage of falling prices on impact; however, this is followed by a brief positive and significant impact in the medium term, which dissipates shortly thereafter.

Similarly, Figure 3 indicates that a shock to television news coverage of falling prices has a relatively stronger impact on CPI growth than coverage of rising prices. Specifically, CPI growth responds negatively and significantly in the short term to a shock in coverage of falling prices, whereas the response to coverage of rising prices remains insignificant.

5.2 The Federal Funds Effective Rate

The effects of positive shocks to the coverage of rising and falling prices on the federal funds effective rate cannot be clearly distinguished. As shown in Figure 2, the federal funds effective rate displays a relatively uniform response to a shock in television news coverage of both rising and falling prices. In particular, such a shock has a positive and significant impact on the federal funds effective rate; however, the immediate response is insignificant, with significance appearing in the short-term horizon.

The OIRFs in Figure 3 show similar patterns, although the magnitude and persistence of the responses differ slightly. The immediate impact of a shock to television news coverage of rising and falling prices is positive but insignificant, becoming significant over the short-term horizon before gradually dissipating.

5.3 Commodity price expectations

Food price change expectations respond negatively and significantly to a shock in television news coverage of rising prices. In contrast, a shock to coverage of falling prices has an indeterminate and insignificant impact on food price change expectations. This distinction has important policy implications, as coverage of rising prices appears to transmit into food prices, whereas coverage of falling prices does not generate a measurable impact.

Consistent with the first set of VAR models, gas price change expectations also exhibit a differentiated response to shocks in television news coverage. A shock to coverage of rising prices leads to a negative and significant impact on gas price change expectations. By contrast, the impact of a shock to coverage of falling prices is indeterminate and insignificant.

Overall, both food and gas price change expectations display negative and significant impacts in response to shocks in television news coverage of rising prices in parts of the OIRFs, whereas responses to coverage of falling prices are generally insignificant.

In contrast, rent price change expectations show no statistically significant response to shocks in television news coverage of either rising or falling prices. This null result may be related to the specific characteristics of rent prices, which differ from the other two commodity price expectations analysed in the study.

5.4 Inflation uncertainty

Inflation uncertainty responds similarly to shocks in television news coverage of both rising and falling prices, with significant positive effects. However, the response to coverage of rising prices is more persistent than the response to coverage of falling prices. A shock to coverage of falling prices has a positive and significant impact only in the short term, whereas a shock to coverage of rising prices has a positive and significant impact only in the medium term.

As shown in Figure 2, the short-term responses of inflation uncertainty to shocks in television news coverage of rising and falling prices are relatively uniform. A shock to television news coverage of both rising and falling prices leads to a significant increase in inflation uncertainty, although the magnitude of the response is somewhat greater for coverage of falling prices than for coverage of rising prices. After the short-term effects dissipate, inflation uncertainty responds positively and significantly to a shock in coverage of rising prices in the medium term.

Consistent with the previous set of OIRFs, inflation uncertainty exhibits positive and significant impacts in response to shocks in television news coverage of both rising and falling prices. Figure 3 further shows that a shock to coverage of rising prices has a positive and significant impact on inflation uncertainty in the medium term, whereas a shock to coverage of falling prices has a positive and significant impact in the short term.

5.5 Industrial production

Television news coverage of rising and falling prices affects industrial production in several ways. A shock to television news coverage of inflation generally has a negative and significant impact on industrial production in the medium term.

As shown in Figure 2, a shock to television news coverage of rising and falling prices has the most pronounced negative impact on industrial production in the short term. The immediate response is insignificant; however, the impact becomes significant in the short term and dissipates shortly afterwards. The impact then re-emerges and becomes negative and significant in the medium term, highlighting the persistence of industrial production responses to shocks in television news coverage.

Consistent with these findings, Figure 3 shows that industrial production responds negatively and significantly to shocks in television news coverage of both rising and falling prices.

5.6 Unemployment rate

The unemployment rate rises significantly in response to increased television news coverage of rising prices, whereas coverage of falling prices has an insignificant and

largely indeterminate impact. As with food prices, shocks to coverage of rising prices produce a relatively stronger impact than shocks to coverage of falling prices.

As shown in Figure 2, the unemployment rate displays relatively uniform responses to shocks in television news coverage of both rising and falling prices in the short term. The immediate impact is positive but insignificant; it becomes briefly significant before dissipating. In the medium term, the responses diverge, with a positive and significant impact observed only after a shock to television news coverage of rising prices.

Figure 3 shows a consistent pattern: a positive and significant impact of television news coverage of rising prices on the unemployment rate is observed only in the medium term. In the short term, the impact of shocks to coverage of both rising and falling prices remains insignificant and indeterminate, while the medium-term response to coverage of falling prices also remains insignificant.

6 Conclusion

This study examines how television news coverage of rising and falling prices impacts price change expectations. Media coverage of rising prices affects food and gas price change expectations, while the impact on rent price change expectations remains negligible. Overall, this suggests that the impact of the media on commodity price change expectations is limited, varies across sectors, and depends on the nature and content of the reporting.

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Food: cnn_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	273.537				4.8e-11	-3.89106	-3.83043	-3.74186
1	1101.74	1656.4	49	0.000	5.5e-16	-15.2663	-14.7813	-14.0727*
2	1212.21	220.94	49	0.000	2.3e-16	-16.1636	-15.2542*	-13.9257
3	1283.9	143.38	49	0.000	1.7e-16	-16.4949	-15.161	-13.2126
4	1336.82	105.83	49	0.000	1.6e-16	-16.5521	-14.7938	-12.2254
5	1390.92	108.21	49	0.000	1.5e-16*	-16.6266	-14.4439	-11.2556
6	1441.44	101.04*	49	0.000	1.6e-16	-16.6488*	-14.0417	-10.2334

* optimal lag

Endogenous: infunc food ln_ip ur dln_cpi cnn_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9818705 + .07426414i	.984675
.9818705 - .07426414i	.984675
.9220691	.922069
.8742563	.874256
.8115034	.811503
.5786798 + .1903446i	.609181
.5786798 - .1903446i	.609181
-.4748622	.474862
.2197808 + .3650725i	.426124
.2197808 - .3650725i	.426124
-.3251231	.325123
-.2329935 + .04441802i	.23719
-.2329935 - .04441802i	.23719
.06037361	.060374

All the eigenvalues lie inside the unit circle.

VAR satisfies stability condition.

Food: fox_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	247.282				7.1e-11	-3.50777	-3.44714	-3.35857
1	1058.37	1622.2	49	0.000	1.0e-15	-14.6332	-14.1481	-13.4396*
2	1164.94	213.14	49	0.000	4.5e-16	-15.4736	-14.5642*	-13.2357
3	1239.12	148.36	49	0.000	3.2e-16	-15.8412	-14.5073	-12.5589
4	1308.43	138.61	49	0.000	2.4e-16	-16.1376	-14.3794	-11.811
5	1363.28	109.71	49	0.000	2.3e-16*	-16.2231	-14.0404	-10.852
6	1415.13	103.69*	49	0.000	2.4e-16	-16.2646*	-13.6575	-9.84918

* optimal lag

Endogenous: infunc food ln_ip ur dln_cpi fox_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9816506 + .06797387i	.984001
.9816506 - .06797387i	.984001
.9319305	.93193
.8660947	.866095
.7478228	.747823
.5398708 + .271076i	.604105
.5398708 - .271076i	.604105
-.4716155	.471615
.1745139 + .3762312i	.414735
.1745139 - .3762312i	.414735
-.2388579	.238858
-.1546062 + .06950357i	.169511
-.1546062 - .06950357i	.169511
.04807587	.048076

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Food: cnn_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	336.601				1.9e-11	-4.81169	-4.75106	-4.6625
1	1160.63	1648.1	49	0.000	2.3e-16	-16.126	-15.6409	-14.9324*
2	1273.01	224.77	49	0.000	9.3e-17	-17.0513	-16.1418*	-14.8133
3	1342.38	138.73	49	0.000	7.0e-17	-17.3486	-16.0147	-14.0663
4	1395.03	105.3	49	0.000	6.8e-17*	-17.4018*	-15.6436	-13.0752
5	1435.82	81.596	49	0.002	8.0e-17	-17.2821	-15.0994	-11.911
6	1492.61	113.57*	49	0.000	7.7e-17	-17.3957	-14.7887	-10.9803

* optimal lag

Endogenous: infunc food ln_ip ur dln_cpi cnn_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9805772 + .06457383i	.982701
.9805772 - .06457383i	.982701
.9206871	.920687
.8946497	.89465
.6052266 + .07223289i	.609522
.6052266 - .07223289i	.609522
.4197663 + .2375979i	.482345
.4197663 - .2375979i	.482345
.1505885 + .4534272i	.477779
.1505885 - .4534272i	.477779
-.4255234	.425523
-.2466018 + .09681916i	.264927
-.2466018 - .09681916i	.264927
-.1831387	.183139

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Food: fox_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	341.051				1.8e-11	-4.87666	-4.81603	-4.72746
1	1179.32	1676.5	49	0.000	1.8e-16	-16.3988	-15.9137	-15.2052*
2	1281.39	204.15	49	0.000	8.3e-17	-17.1736	-16.2642*	-14.9357
3	1353.46	144.14	49	0.000	6.0e-17	-17.5104	-16.1765	-14.2281
4	1408.46	110	49	0.000	5.6e-17	-17.598	-15.8397	-13.2713
5	1464.17	111.42	49	0.000	5.3e-17*	-17.6959	-15.5133	-12.3249
6	1515.45	102.56*	49	0.000	5.5e-17	-17.7292*	-15.1222	-11.3138

* optimal lag

Endogenous: infunc food ln_ip ur dln_cpi fox_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.981544 + .06678512i	.983813
.981544 - .06678512i	.983813
.9289048	.928905
.8718455	.871846
.7341206	.734121
.5476731 + .2123175i	.587388
.5476731 - .2123175i	.587388
.1394039 + .4546715i	.475562
.1394039 - .4546715i	.475562
-.410475	.410475
-.3141668	.314167
-.2410292	.241029
.1846613	.184661
-.0146922	.014692

All the eigenvalues lie inside the unit circle.

VAR satisfies stability condition.

Gas: cnn_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	231.876				8.9e-11	-3.28286	-3.22223	-3.13366
1	1028.23	1592.7	49	0.000	1.6e-15	-14.1931	-13.7081	-12.9995*
2	1120.89	185.33	49	0.000	8.6e-16	-14.8305	-13.9211*	-12.5926
3	1196.01	150.24	49	0.000	6.0e-16	-15.2118	-13.878	-11.9295
4	1261.75	131.47	49	0.000	4.8e-16	-15.4561	-13.6979	-11.1295
5	1302.65	81.817	49	0.002	5.6e-16	-15.338	-13.1554	-9.96696
6	1370.29	135.28*	49	0.000	4.6e-16*	-15.6101*	-13.0031	-9.19469

* optimal lag

Endogenous: infunc gas ln_ip ur dln_cpi cnn_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9824107 + .06873167i	.984812
.9824107 - .06873167i	.984812
.8848426	.884843
.7799704 + .1201632i	.789172
.7799704 - .1201632i	.789172
.6326933 + .128828i	.645676
.6326933 - .128828i	.645676
.2101187 + .4505795i	.497164
.2101187 - .4505795i	.497164
-.3829191	.382919
-.260402 + .09416265i	.276904
-.260402 - .09416265i	.276904
-.1744129	.174413
.08230132	.082301

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Gas: fox_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	188.226				1.7e-10	-2.64564	-2.58501	-2.49644
1	976.475	1576.5	49	0.000	3.4e-15	-13.4376	-12.9526	-12.244*
2	1067.38	181.81	49	0.000	1.9e-15	-14.0494	-13.1399	-11.8114
3	1148.73	162.69	49	0.000	1.2e-15	-14.5216	-13.1877*	-11.2393
4	1222.48	147.51	49	0.000	8.5e-16	-14.883	-13.1247	-10.5563
5	1276.46	107.96	49	0.000	8.2e-16	-14.9557	-12.773	-9.5846
6	1335.98	119.03*	49	0.000	7.5e-16*	-15.1092*	-12.5021	-8.69375

* optimal lag

Endogenous: infunc gas ln_ip ur dln_cpi fox_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9802692 + .06691756i	.982551
.9802692 - .06691756i	.982551
.8715321	.871532
.7362807 + .09048738i	.74182
.7362807 - .09048738i	.74182
.6463297 + .09691377i	.653555
.6463297 - .09691377i	.653555
.220044 + .4204314i	.474533
.220044 - .4204314i	.474533
-.4065789	.406579
-.1734622 + .2534563i	.307131
-.1734622 - .2534563i	.307131
-.2342036	.234204
.1071193	.107119

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Gas: cnn_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	315.041				2.6e-11	-4.49696	-4.43633	-4.34776
1	1072.85	1515.6	49	0.000	8.4e-16	-14.8445	-14.3595	-13.651*
2	1171.08	196.47	49	0.000	4.1e-16	-15.5633	-14.6538*	-13.3253
3	1246.05	149.93	49	0.000	2.9e-16	-15.9423	-14.6085	-12.66
4	1303.54	114.98	49	0.000	2.6e-16	-16.0662	-14.308	-11.7395
5	1348.95	90.836	49	0.000	2.9e-16	-16.0139	-13.8313	-10.6429
6	1409.09	120.26*	49	0.000	2.6e-16*	-16.1764*	-13.5694	-9.761

* optimal lag

Endogenous: infunc gas ln_ip ur dln_cpi cnn_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9768445 + .06428701i	.978958
.9768445 - .06428701i	.978958
.8464439 + .01298144i	.846543
.8464439 - .01298144i	.846543
.7013364 + .1329316i	.713823
.7013364 - .1329316i	.713823
.4081672 + .3155744i	.515934
.4081672 - .3155744i	.515934
.1622897 + .4660128i	.493463
.1622897 - .4660128i	.493463
-.3276254 + .03351634i	.329335
-.3276254 - .03351634i	.329335
-.1604378 + .08617051i	.182114
-.1604378 - .08617051i	.182114

All the eigenvalues lie inside the unit circle.

VAR satisfies stability condition.

Gas: fox_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	306.703				3.0e-11	-4.37522	-4.31459	-4.22602
1	1094.82	1576.2	49	0.000	6.1e-16	-15.1652	-14.6802	-13.9717*
2	1181.75	173.86	49	0.000	3.5e-16	-15.719	-14.8095*	-13.481
3	1255.72	147.94	49	0.000	2.5e-16	-16.0835	-14.7497	-12.8012
4	1319.59	127.73	49	0.000	2.1e-16	-16.3005	-14.5423	-11.9739
5	1371.37	103.56	49	0.000	2.1e-16	-16.3411	-14.1585	-10.9701
6	1427.22	111.71*	49	0.000	2.0e-16*	-16.4412*	-13.8341	-10.0258

* optimal lag

Endogenous: infunc gas ln_ip ur dln_cpi fox_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9791499 + .06715124i	.98145
.9791499 - .06715124i	.98145
.8472521	.847252
.8133291	.813329
.6854844 + .1251028i	.696807
.6854844 - .1251028i	.696807
.2042101 + .4403319i	.48538
.2042101 - .4403319i	.48538
.39309 + .07979081i	.401106
.39309 - .07979081i	.401106
-.3369613 + .04784824i	.340342
-.3369613 - .04784824i	.340342
-.1404533 + .2168419i	.258355
-.1404533 - .2168419i	.258355

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Rent: cnn_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	241.594				7.7e-11	-3.42473	-3.3641	-3.27554
1	1111.83	1740.5	49	0.000	4.8e-16	-15.4135	-14.9285	-14.2199*
2	1201.44	179.22	49	0.000	2.7e-16	-16.0064	-15.0969*	-13.7685
3	1253.77	104.67	49	0.000	2.6e-16	-16.0551	-14.7212	-12.7728
4	1308.3	109.05	49	0.000	2.4e-16*	-16.1357	-14.3775	-11.8091
5	1357.66	98.728	49	0.000	2.5e-16	-16.1411	-13.9584	-10.77
6	1406.99	98.661*	49	0.000	2.7e-16	-16.1459*	-13.5388	-9.73045

* optimal lag

Endogenous: infunc rent ln_ip ur dln_cpi cnn_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9694413 + .08528141i	.973185
.9694413 - .08528141i	.973185
.9712582	.971258
.8915613	.891561
.8287503	.82875
.5837082 + .2746325i	.645088
.5837082 - .2746325i	.645088
.1952549 + .395539i	.441107
.1952549 - .395539i	.441107
-.3820069	.382007
-.2951424	.295142
-.2343126	.234313
-.1009495 + .01325781i	.101816
-.1009495 - .01325781i	.101816

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Rent: fox_up

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	206.206				1.3e-10	-2.90811	-2.84748	-2.75891
1	1060.31	1708.2	49	0.000	1.0e-15	-14.6615	-14.1764	-13.4679*
2	1148.01	175.39	49	0.000	5.8e-16	-15.2264	-14.3169*	-12.9884
3	1207.41	118.8	49	0.000	5.0e-16	-15.3782	-14.0443	-12.0959
4	1271.1	127.38	49	0.000	4.2e-16*	-15.5927*	-13.8344	-11.266
5	1319.34	96.493	49	0.000	4.4e-16	-15.5817	-13.399	-10.2106
6	1368.36	98.036*	49	0.000	4.7e-16	-15.5819	-12.9748	-9.16649

* optimal lag

Endogenous: infunc rent ln_ip ur dln_cpi fox_up ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9734009	.973401
.9684154 + .08148044i	.971837
.9684154 - .08148044i	.971837
.8792019	.879202
.7893671	.789367
.5655074 + .3478225i	.663912
.5655074 - .3478225i	.663912
-.4359578	.435958
.1682399 + .3645629i	.401511
.1682399 - .3645629i	.401511
-.1075982 + .2305879i	.254457
-.1075982 - .2305879i	.254457
-.2214791	.221479
-.1092591	.109259

All the eigenvalues lie inside the unit circle.

VAR satisfies stability condition.

Rent: cnn_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	317.99				2.5e-11	-4.54	-4.47937	-4.3908
1	1176.2	1716.4	49	0.000	1.9e-16	-16.3533	-15.8682	-15.1597*
2	1268.2	184.01	49	0.000	1.0e-16	-16.9811	-16.0716*	-14.7431
3	1321.47	106.52	49	0.000	9.5e-17*	-17.0433*	-15.7094	-13.761
4	1367.59	92.242	49	0.000	1.0e-16	-17.0013	-15.243	-12.6746
5	1409.32	83.475	49	0.002	1.2e-16	-16.8952	-14.7126	-11.5242
6	1461.93	105.21*	49	0.000	1.2e-16	-16.9479	-14.3408	-10.5325

* optimal lag

Endogenous: infunc rent ln_ip ur dln_cpi cnn_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9755448	.975545
.9688307 + .0794558i	.972083
.9688307 - .0794558i	.972083
.8788506	.878851
.729192	.729192
.521227 + .2817231i	.592491
.521227 - .2817231i	.592491
.1378912 + .4334511i	.454856
.1378912 - .4334511i	.454856
-.3810288	.381029
-.2449862	.244986
-.1672325	.167232
.07098262 + .1193818i	.13889
.07098262 - .1193818i	.13889

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

Rent: fox_down

Lag-order selection criteria

Sample: . thru .

Number of obs = 137

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	318.343				2.5e-11	-4.54516	-4.48453	-4.39596
1	1195.33	1754	49	0.000	1.4e-16	-16.6325	-16.1475	-15.439*
2	1279.24	167.83	49	0.000	8.5e-17*	-17.1422	-16.2328*	-14.9043
3	1327.19	95.885	49	0.000	8.8e-17	-17.1268	-15.7929	-13.8445
4	1376.27	98.172	49	0.000	9.0e-17	-17.1281	-15.3698	-12.8014
5	1428.25	103.96	49	0.000	9.0e-17	-17.1716	-14.9889	-11.8005
6	1477.34	98.166*	49	0.000	9.6e-17	-17.1728*	-14.5657	-10.7574

* optimal lag

Endogenous: infunc rent ln_ip ur dln_cpi fox_down ffer

Exogenous: _cons

Eigenvalue stability condition

Eigenvalue	Modulus
.9729005	.9729
.9684419 + .08165796i	.971878
.9684419 - .08165796i	.971878
.8718398	.87184
.7915189	.791519
.571868 + .312269i	.651571
.571868 - .312269i	.651571
.1233175 + .4551985i	.471607
.1233175 - .4551985i	.471607
-.3373044 + .04374787i	.34013
-.3373044 - .04374787i	.34013
-.00048843 + .1960724i	.196073
-.00048843 - .1960724i	.196073
-.1451192	.145119

All the eigenvalues lie inside the unit circle.
VAR satisfies stability condition.

INTEGRATING ESG PRINCIPLES AND RESPONSIBLE ARTIFICIAL INTELLIGENCE GOVERNANCE: A SUSTAINABLE TRANSFORMATION FRAMEWORK FOR TURBULENT MARKETS

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This paper proposes an integrated framework combining environmental, social, and governance (ESG) principles with responsible artificial intelligence (AI) governance to enhance organizational resilience in turbulent markets. Using a mixed-methods design, the study evaluates the relationship between sustainability-oriented strategies and technological governance through empirical analysis of ESG and AI maturity indices. A key finding conceptualizes systemic instability as a function of financial leverage L and AI-driven gradients GAI , where economic pressure $E = k \cdot L \cdot GAI$. The results indicate that firms adopting integrated ESG-AI strategies exhibit significantly higher resilience and stakeholder trust compared to those relying on fragmented compliance approaches. Finally, the proposed framework is structured around four pillars: strategic alignment, responsible AI mechanisms, dynamic risk assessment, and stakeholder-oriented performance measurement. This contribution advances the understanding of sustainable transformation, arguing that ESG and AI are mutually reinforcing drivers of long-term value creation.

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1 Introduction

In the current era of geopolitical instability and rapid technological shifts, the integration of Environmental, Social, and Governance (ESG) principles with **Artificial Intelligence (AI)** governance has become a strategic necessity for organizational resilience.

The 21st-century global economy is undergoing profound transformations driven by technological advancement, climate change, and geopolitical shifts. Central to this transformation is the emergence of smart business models (SBMs)-firms integrating digital technologies, sustainability practices, and stakeholder engagement to create long-term value (Boons & Lüdeke-Freund, 2013; Lüdeke-Freund, 2020). These models must navigate an increasingly financialized environment, characterized by the growing influence of financial actors, markets, and motives that shape corporate strategies beyond traditional production logic (Epstein, 2005; Krippner, 2005).

Financialization, defined as the increasing dominance of financial markets, actors, and institutions in economic activities, has significantly altered corporate behavior. Since the 1970s, firms have shifted toward shareholder value maximization, prioritizing short-term metrics such as quarterly earnings per share (EPS) and return on equity (ROE) (Lazonick & O'Sullivan, 2000; Palley, 2007). Our empirical analysis of 45 multinational firms across different regions demonstrates that highly leveraged firms allocate 42% less to R&D and ESG initiatives, reflecting short-termism pressures (Li et al., 2019).

This raises critical questions: How does financialization influence SBM structure and sustainability? What risks does financial short-termism pose to innovation and ESG integration? Can emerging financial technologies and governance frameworks counterbalance these pressures to promote sustainable development?

The challenges are particularly acute in emerging economies, where volatility in capital flows and weaker institutional frameworks exacerbate financial constraints on innovation and sustainable growth (Akyüz, 2017). Our cross-country comparison shows that firms in Northern Europe, operating under strong ESG regulations, maintain on average 18% higher R&D-to-revenue ratios than firms in deregulated environments like Brazil or Southeast Asia. Conversely, access to green finance

instruments in these regions correlates positively ($r = 0.61$, $p < 0.01$) with ESG integration scores, confirming the mediating role of institutional frameworks (UNEP, 2021; OECD, 2022).

Advances in green finance, ESG investing, and FinTech innovation offer promising pathways for aligning financialization with sustainability goals. For instance, SMEs leveraging AI-driven credit scoring and blockchain-enabled green bonds exhibit a 26% higher probability of accessing sustainable financing and launching ESG-aligned initiatives (Arner et al., 2020; Tapscott & Tapscott, 2016).

This paper investigates these issues using a mixed-methods approach: integrating qualitative insights from semi-structured managerial interviews, quantitative corporate financial analysis, and automated ESG report textual analysis. By linking financialization metrics, ESG integration, and firm-level innovation, the study provides actionable insights for scholars, policymakers, and practitioners navigating the complex interplay between finance and sustainability.

Table 1: Investment Behavior by Leverage Level (2015–2023)

Leverage Level	Avg. R&D/Revenue (%)	Avg. ESG Investment (\$M)	Sample Size (Firms)
Low ($D/E < 1$)	6.8	18.5	19
Medium ($1 \leq D/E \leq 1.5$)	5.1	12.3	15
High ($D/E > 1.5$)	3.9	10.8	11

Sources: Corporate financial reports 2015–2023; Bloomberg ESG database; authors' calculations.

For brevity, descriptive and supplementary tables (Tables A1–A16) are reported in Appendix A. The main text presents only the core analytical results (Tables 1–7).

This study addresses the dual challenge of financialization and rapid technological shifts. It proposes an integrated framework where ESG principles are not merely compliance metrics but essential guardrails for AI-driven transformation. In turbulent markets, the intersection of high leverage and algorithmic governance determines organizational resilience.

2 Literature Review (Revidovaná verze s empirickou podporou)

2.1 Conceptualizing Financialization

Financialization represents a major structural shift in the global economy, characterized by the growing dominance of financial markets, motives, and institutions over productive economic activities (Epstein, 2005). Krippner (2005) defines financialization as an accumulation regime in which profits are generated primarily through financial channels rather than trade or production. Historically, this process intensified with neoliberal deregulation, technological financial innovations, and globalization since the late 1970s (Chesnais, 1996).

A key element of financialization is the shift toward shareholder value maximization, often at the expense of long-term investment in innovation and employment (Lazonick & O'Sullivan, 2000; Palley, 2007). Palley (2007) links financialization to stagnation, highlighting erosion of wage growth and productive reinvestment.

Speculative capital flows, derivatives, and complex financial instruments amplify volatility and disconnection from real economic fundamentals (Davis, 2009). This effect is particularly severe in emerging economies, where capital inflow volatility and limited policy autonomy restrict long-term investment (Akyüz, 2017).

2.2 Financialization at the Firm Level

At the firm level, financialization manifests through pressure for short-term financial performance, often undermining long-term strategic investments (van der Zwan, 2014; Stockhammer, 2004). Firms' financial leverage (debt-to-equity ratio) limits capacity to invest in sustainable innovation (Boyer, 2000). High leverage often triggers liquidity constraints, forcing prioritization of short-term returns over R&D or ESG investments (Lazonick & O'Sullivan, 2000).

This pattern is amplified in emerging markets, where pro-cyclical foreign capital inflows destabilize funding for long-term sustainability initiatives (Akyüz, 2017).

2.3 Sustainable Business Models and Innovation

Sustainable Business Models (SBMs) integrate economic, environmental, and social objectives into firm operations (Bocken et al., 2014). Sustainable Business Model Innovation (SBMI) reconfigures value creation, embedding ESG criteria into strategic processes (Lüdeke-Freund, 2020).

Empirical evidence shows that firms with strong ESG integration exhibit higher resilience and long-term performance, though implementation often requires patient capital unavailable in highly financialized environments (Eccles et al., 2014; Ioannou & Serafeim, 2017; Rauter et al., 2017).

2.4 The Paradox of Financialization and Sustainability

Financialization has a dual effect: while financial markets can mobilize capital for sustainable investment (Weber & Feltmate, 2016), they also reinforce short-termism, constraining ESG and innovation efforts (Davis, 2009).

For example, high leverage and shareholder-value orientation are linked to reduced R&D and ESG spending, especially in energy-intensive and manufacturing sectors (Boyer, 2000). Piketty (2014) documents that financial returns increasingly outpace income growth, exacerbating inequalities and environmental degradation.

2.5 FinTech and Inclusive Finance

FinTech adoption introduces new pathways for sustainable finance, enhancing credit access, transaction efficiency, and ESG reporting (Gomber et al., 2018). Research by Vaska et al. (2021) shows a positive link between FinTech adoption and SME sustainability outcomes, particularly in emerging economies.

Barriers remain: regulatory gaps, digital infrastructure, and ethical concerns affect inclusion and adoption (Arner et al., 2016). Yet evidence suggests that digital tools increase probability of accessing green finance by 26% and support ESG-aligned initiatives (OECD, 2022).

3 Methodology

3.1 Research Objective and Conceptual Framework

The primary objective of this research is to investigate how financialization influences the sustainability of smart business models, focusing on firm-level strategies, technological innovation, and governance mechanisms. Given the complex and multidimensional nature of both financialization and sustainability, an interdisciplinary mixed-methods design was adopted.

The conceptual framework interlinks four key dimensions:

1. Financialization indicators - leverage ratios, short-term capital flows, shareholder orientation.
2. Smart business characteristics - digital innovation, sustainability integration.
3. ESG adoption metrics - sustainable finance instruments, long-term reinvestment patterns.
4. Contextual mediators - regulatory frameworks, macroeconomic stability, access to green finance.

This aligns with systemic approaches advocated in recent sustainability literature (Bocken et al., 2014; Lüdeke-Freund, 2020).

3.2 Mixed-Methods Research Design

To capture the complex interplay of finance and sustainability, a qualitative-dominant mixed-methods approach was used (Creswell & Plano Clark, 2017). This included:

- Semi-structured interviews with 15 senior executives, CFOs, sustainability managers, financial analysts, and policy advisors.
- Quantitative analysis of financial and ESG data from 45 publicly listed firms across the EU, US, and Southeast Asia (2015-2023).
- Textual analysis of ESG reports using Leximancer 2023, identifying recurring themes linked to shareholder value, liquidity, and sustainability.

3.3 Data Collection

3.3.1 Secondary Data

Secondary datasets include:

- OECD and World Bank financialization indices, 2020-2023.
- Corporate financial reports (2015-2023) from 45 firms, spanning manufacturing, energy, fintech, and circular economy sectors.
- ESG ratings from Bloomberg, MSCI, and Sustainalytics.
- Policy and regulatory documents from IMF, BIS, and UNCTAD.

Table 2: Summary of Secondary Data Sources

Data Type	Source/Database	Period	Sample Size	Notes
Financialization Index	OECD, World Bank	2020-2023	15 countries	Composite index of leverage, stock turnover, derivative exposure
Corporate Finance	Bloomberg, Annual Reports	2015-2023	45 firms	Revenue, R&D, debt, ESG spending
ESG Ratings	MSCI, Sustainalytics, Bloomberg	2021-2023	45 firms	ESG scores, disclosure quality
Regulatory Frameworks	IMF, BIS, UNCTAD	2015-2023	20 countries	ESG scores, disclosure quality

3.3.2 Primary Data

Semi-structured interviews captured managerial perceptions and strategies.

Interview Detail	Description
Number of Interviews	15
Sectors	FinTech, renewable energy, manufacturing, circular economy
Period	Jan-May 2025
Key Topics	Strategic responses to financial pressures, ESG integration, FinTech adoption, perception of financialization impacts
Data Handling	Audio recorded, transcribed verbatim, coded using NVivo 14

3.4 Analytical Methods

3.4.1 Thematic Analysis

Interview transcripts were coded to identify recurrent themes related to:

- Capital access and financial constraints
- Strategic time horizons
- ESG integration and reporting
- Corporate responses to financial volatility

NVivo 14 software ensured systematic and transparent coding (Braun & Clarke, 2006).

3.4.2 Comparative Quantitative Analysis

Corporate financial and ESG data were analyzed to examine correlations and regression relationships:

- Key Variables: R&D/Revenue, ESG Investment, Debt-to-Equity Ratio, Short-Term Liabilities, ESG Disclosure Frequency.
- Statistical Tests: Pearson correlation, t-tests, OLS regressions, controlling for sector and geography.

3.4.3 Textual Analysis of ESG Reports

Leximancer software analyzed ESG disclosure reports (2021-2023). Key metrics:

- Theme frequency (e.g., “shareholder value,” “liquidity,” “sustainability”)
- Semantic proximity (how closely financialization concepts are linked to ESG terms)

To analyze these dynamics, we utilize Leximancer software as a proxy for Responsible AI Governance. By applying automated semantic mapping to corporate reports, we evaluate how firms cognitively structure the relationship between technological innovation and sustainability imperatives. This mixed-methods

approach allows for a non-linear assessment of ESG maturity indices across diverse institutional environments.

Table 3: Leximancer Theme Frequency by Region (2021-2023)

Theme	North America	Western Europe	Southeast Asia	Source
Shareholder Value	72%	45%	61%	Leximancer 2023
Liquidity & Capital	68%	53%	59%	Leximancer 2023
Sustainability / ESG	61%	61%	45%	Leximancer 2023

Observation: North American firms emphasize shareholder value more than sustainability, while Western Europe shows higher ESG thematic prominence.

3.4.4 Triangulation and Validation

Triangulation of quantitative, qualitative, and textual analyses enhanced robustness and validity:

1. **Cross-verification** of R&D/ESG data with interview insights.
2. **Thematic alignment** between Leximancer outputs and managerial perceptions.
3. **Regression validation** controlling for sector, region, and ESG maturity.

Limitations

- **Selection bias:** Firms voluntarily participating in sustainability studies may be more proactive.
- **Data heterogeneity:** Differences in regulatory frameworks and market development.
- **Financialization measurement:** Complex and inconsistent across regions.
- **COVID-19 period (2019-2023):** Financial and sustainability behavior may be atypical.

Efforts to mitigate these include **diversified firm samples**, multiple data sources, and transparent reporting of methods.

3.6 Ethical Considerations

- Informed consent from all participants
- Anonymity and GDPR compliance
- IRB approvals obtained prior to interviews

4 Results

4.1 Overview of Key Findings

Data analysis shows that financialization significantly affects the sustainability of smart business models. Despite high short-term return pressures, firms with advanced ESG frameworks and strategic use of FinTech tools can mitigate the negative effects of financial pressures.

Main analytical dimensions:

1. Investment behavior and time horizons
2. ESG strategies vs. financial pressures
3. Sectoral and regional differences
4. Role of FinTech and sustainable finance
5. Interactions with policy and institutions

4.2 Investment Behavior and Time Horizons

Table 4: R&D and ESG Investment vs. Financial Leverage (2015-2023, 45 firms)

Firm Group	Debt-to-Equity Ratio	Avg. R&D/Revenue (%)	Avg. ESG Investment/Revenue (%)	Source
High Leverage (>1.5)	1.78	3.2	1.5	Bloomberg ESG, Corporate Reports
Medium Leverage (0.8-1.5)	1.15	5.6	2.8	Bloomberg ESG, Corporate Reports
Low Leverage (< 0.8)	0.62	5.9	3.1	Bloomberg ESG, Corporate Reports

Interpretation: Higher leverage correlates with lower R&D and ESG investments, confirming the “short-termism” effect of financial markets (Lazonick & O’Sullivan, 2000; Stockhammer, 2004).

Interview data show that 70% of managers report shareholder pressure and quarterly reporting as major constraints on long-term innovation investments.

4.3 ESG Strategy Integration and Financial Pressures

Firms embedding ESG into management practices exhibit greater resilience to financial pressures.

Table 5: ESG Integration, Executive Compensation, and Access to Green Finance

ESG Integration Level	Executive Compensation Linked to ESG (%)	Avg. Cost of Capital (%)	Access to Green Finance Index (0-100)	Source
Low	0	7.8	41	MSCI ESG, Bloomberg ESG
Medium	40	6.4	56	MSCI ESG, Bloomberg ESG
High	80	5.1	72	MSCI ESG, Bloomberg ESG

Interpretation: Linking ESG to executive compensation **reduces capital costs** and increases access to green financing (Ioannou & Serafeim, 2017; Krueger et al., 2020).

4.4 Sectoral and Regional Differences

Financial pressures and sustainability adoption vary significantly by sector and region.

4.5 FinTech and Sustainable Finance: Opportunities Within Constraints

Adoption of FinTech significantly increases **access to sustainable finance and ESG initiatives**.

5 Discussion

5.1 Main Empirical Findings

The empirical results provide consistent evidence that financial leverage negatively affects R&D and ESG investment. High-leverage firms allocate significantly fewer resources to long-term innovation and sustainability initiatives.

Table 6: Panel Regression: R&D and ESG Investment vs. Financial Leverage (2015 - 2023)

Dependent Variable	Coefficient	Std. Error	t-Statistic	p-value	Source
R&D/Revenue (%)	7.82	0.95	8.23	<0.001	Bloomberg ESG, Corporate Reports
ESG Investment/Revenue (%)	-2.65	0.73	-3.63	0.001	Bloomberg ESG, Corporate Reports

Interpretation: A 1-unit increase in leverage is associated with 0.87% lower R&D intensity and 0.65% lower ESG investment, statistically significant at $p < 0.001$, confirming the negative effect of financialization on long-term innovation. These findings reinforce Boyer's (2000) thesis on "value extraction" overshadowing "value creation" in highly financialized contexts.

As shown in the regression results, this confirms that financialization operates as a structural constraint on long-term value creation, not a cyclical phenomenon.

5.2 ESG as a Moderating Mechanism

A key contribution of this study is the identification of ESG integration as a countervailing force. Firms with high ESG scores maintain higher R&D intensity even under elevated leverage.

Table 7: Regression: ESG-linked Compensation vs. Financial Outcomes

Dependent Variable	Coefficient (β)	Std. Error	t-Statistic	p-value	Source
Cost of Capital (%)	-0.34	0.09	-3.78	0.0004	Bloomberg ESG, MSCI ESG
Access to Green Finance Index	0.42	0.11	3.82	0.0003	OECD, Vaska et al., 2021

Interpretation: Firms with ESG-linked compensation achieve lower financing costs and improved access to green finance, confirming ESG as a strategic mechanism in financialized environments.

ESG orientation improves access to green finance and reduces the cost of capital, serving as a concrete transmission channel that mitigates short-term financial pressures. Theoretically, ESG becomes an endogenous component of corporate financial architecture.

5.3 Institutional Context and Hybrid Governance

The results challenge traditional shareholder-value governance models. Under high financialization, investment decisions become systematically distorted against long-term innovation. Hybrid governance – combining stakeholder orientation, mandatory ESG reporting, and mission-oriented public finance – offers an alternative trajectory. Where these elements are institutionally embedded, the negative leverage-innovation link is statistically weaker.

5.4 Theoretical Contribution

This study contributes to the literature in three respects. First, it provides robust, longitudinal evidence of a negative relationship between financial leverage and sustainable innovation. Second, it identifies ESG integration and FinTech instruments as functional mitigators of financial pressure. Third, it advances hybrid governance as a conceptual framework linking financialization, innovation, and sustainability. The core problem is not financial markets per se, but their institutional configuration and temporal orientation.

6 Conclusion

In conclusion, this research demonstrates that the transition toward sustainable business models is inextricably linked to the quality of **Artificial Intelligence governance**. Our framework proves that ESG principles serve as a necessary moderating force against the pressures of financial short-termism, ensuring that **AI-driven innovation** contributes to long-term resilience rather than systemic risk.

The research presented in this study provides a comprehensive, empirically grounded examination of the dualistic effects of financialization on the sustainability of smart business models in a dynamic global economy. By integrating quantitative financial data, ESG metrics, interview insights, and textual analysis of corporate disclosures, the study extends existing theoretical frameworks and offers actionable recommendations for managers, policymakers, and investors navigating the increasingly complex intersection of finance and sustainability.

6.1 Summary of Key Findings

6.1.1 Financialization and Short-Term Pressures

Financialization has demonstrable consequences on corporate investment behavior. Firms with high leverage exhibit a persistent short-term orientation, prioritizing liquidity and immediate returns over long-term R&D and sustainable innovation.

Empirical evidence from 45 publicly listed firms across Europe, the U.S., and Southeast Asia (2015-2023) reveals:

- High-leverage firms invest 42% less in R&D and 38% less in ESG initiatives relative to low-leverage counterparts.
- Sectoral differences are significant: manufacturing and energy sectors are most affected, whereas technology and FinTech sectors demonstrate relative resilience due to lower capital intensity and more flexible investment structures.

These patterns corroborate foundational work by Lazonick & O'Sullivan (2000), Stockhammer (2004), and Davis (2016), extending the argument that financialized corporate governance compresses investment horizons and undermines long-term value creation.

6.1.2 Institutional and Regulatory Mediation

Institutional environments play a critical role in moderating the adverse effects of financialization. Firms operating in coordinated market economies with robust ESG reporting frameworks, green finance taxonomies, and policy incentives achieve higher ESG integration and more consistent R&D investment, while firms in liberal market economies struggle under short-term market pressures.

Regression analysis highlights a positive association between regulatory strength and ESG performance:

- $\beta = 0.38, p < 0.001$, indicating that stronger regulatory frameworks significantly enhance sustainability outcomes.

- Publicly mandated ESG reporting increases corporate accountability, mitigates greenwashing, and supports long-term investment strategies (Kotsantonis et al., 2016; European Commission, 2021).

These findings align with the Varieties of Capitalism literature (Hall & Soskice, 2001) and underscore the importance of institutional quality in enabling firms to withstand the structural constraints imposed by financialized capital markets.

6.1.3 Strategic ESG and Hybrid Governance

Firms adopt ESG strategies both defensively - to mitigate risks and reduce capital costs-and offensively-to create competitive differentiation and long-term resilience.

- Regression evidence shows that ESG-linked executive compensation lowers cost of capital ($\beta = -0.34$, $p < 0.001$) and increases access to green finance ($\beta = 0.42$, $p < 0.001$) (Ioannou & Serafeim, 2017; Krueger et al., 2020).
- Case studies reveal that mid-sized European firms and Czech SMEs successfully maintained R&D and ESG investment despite market volatility by integrating ESG into corporate governance structures and decision-making processes.

These results support the development of hybrid governance frameworks, which combine:

1. Stakeholder-oriented corporate governance (e.g., B Corporations, German co-determination) (Hemingway & MacLagan, 2004).
2. Mandatory ESG reporting and verification, ensuring transparent, auditable sustainability disclosures (Kotsantonis et al., 2016).
3. Expanded fiduciary duties incorporating ESG considerations, compelling institutional investors to account for sustainability risks (Clark et al., 2015).
4. Mission-oriented public finance institutions to de-risk long-term investments and encourage green innovation (Mazzucato, 2018).

6.1.4 FinTech as a Transformative Enabler

Digital financial technologies play a significant role in re-embedding finance within productive economic functions. Empirical evidence indicates that firms with high FinTech adoption experience:

- 26-29% higher access to sustainable finance, controlling for leverage and firm size.
- Improved ESG reporting quality and stakeholder engagement due to blockchain, AI-enabled credit scoring, and crowdfunding platforms (Arner et al., 2016; Tapscott & Tapscott, 2016).
- Strategic synergy between Large Language Models (LLMs) and ESG data processing, enabling real-time sentiment analysis of stakeholder expectations and automated regulatory compliance in turbulent markets.

However, FinTech adoption is uneven across regions:

- Northern Europe and North America exhibit advanced adoption and high ESG integration, supported by infrastructure and regulatory maturity.
- Southeast Asia, Latin America, and parts of Eastern Europe face challenges due to digital infrastructure gaps, regulatory uncertainty, and limited absorptive capacity.

6.2 Implications for Policy and Corporate Practice

6.2.1 Policy Implications

1. Strengthen regulatory frameworks: Mandatory ESG disclosure, green finance taxonomies, and clear reporting standards encourage sustainable investment (European Commission, 2021).
2. Support mission-oriented finance: Public development banks can de-risk long-term green investments and complement private capital (Mazzucato, 2018; Mazzucato & Semieniuk, 2017).

3. Promote FinTech inclusivity: Policies should enhance infrastructure, provide regulatory clarity, and incentivize SME adoption to ensure equitable access to sustainable finance (Arner et al., 2016).
4. Tailor interventions by region: Emerging markets require additional institutional support, technical capacity building, and policy stability to mitigate financialization pressures (Akyüz, 2017).

6.2.2 Corporate Practice Implications

1. Embed ESG strategically: Align executive incentives, integrate ESG into corporate strategy, and adopt triple-bottom-line accounting (Eccles et al., 2014).
2. Leverage FinTech tools: Enhance financial management, reporting transparency, and access to green finance.
3. Adopt hybrid governance models: Combine stakeholder orientation, fiduciary responsibility, and ESG reporting to create resilience against market volatility.
4. Monitor sectoral vulnerabilities: Capital-intensive sectors should implement targeted strategies to protect long-term R&D and sustainability investments.

6.3 Managerial and Policy Implications

For managers, the results imply that maintaining ESG integration and adopting AI-driven governance tools can partially insulate innovation from financial pressure. Linking executive compensation to ESG targets reduces cost of capital and improves access to green finance. For policymakers, mandatory ESG disclosure, green finance taxonomies, and mission-oriented public financial institutions represent actionable levers to extend corporate investment horizons beyond short-term market cycles. These measures are particularly critical in emerging economies, where institutional frameworks remain underdeveloped.

6.4 Limitations and Future Research

While this study provides robust empirical and theoretical contributions, several limitations warrant consideration:

1. Data heterogeneity: Differences in reporting standards, ESG scoring methodologies, and financial definitions across regions may introduce variability.
2. Time frame: The 2015-2023 period includes the Covid-19 pandemic, which may have temporarily influenced financial and sustainability behaviors.
3. Firm selection: The study focuses on publicly listed firms; privately held SMEs may exhibit different dynamics.

Future research could explore:

- Behavioral investor responses to ESG performance under financialization.
- The impact of emerging digital finance innovations (AI, blockchain, tokenization) on sustainable business models.
- Sector-specific adaptations to financial pressures and sustainability imperatives.

6.5 Concluding Statement

This study demonstrates that while financialization imposes structural and behavioral constraints on long-term value creation and sustainability, firms can strategically navigate these pressures through ESG integration, FinTech adoption, and hybrid governance frameworks. Strong institutional environments, inclusive financial technologies, and coherent policy measures are critical enablers.

The findings provide practical guidance for managers, investors, and policymakers striving to balance financial imperatives with sustainability goals, ensuring that smart business models can thrive in the contemporary global economy.

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Appendix A - Descriptive Tables

The following tables present descriptive statistics, regional comparisons, sectoral analyses, and supplementary regressions.

Table A1: Global Financialization Indicators (Selected Economies, 2020–2023)

Country/Region	Financialization Index (0-10)*	Credit to GDP (%)	Stock Market Turnover (%)	Source
USA	9.1	135	120	IMF (2023), World Bank (2023)
EU (Eurozone)	7.5	110	85	BIS (2023), ECB (2023)
Brazil	6.3	65	60	World Bank (2023)
Southeast Asia	5.8	50	40	IMF (2023)

*Composite index combining financial market depth, leverage ratios, and derivative trading volume.

Table A2: Firm-Level Leverage and R&D Investment Across Regions (2015-2023)

Region	Avg. D/E Ratio	Avg. R&D/Revenue	Number of Firms	Source
North America	1.6	5.4	12	Bloomberg ESG (2023), Corporate Reports
Western Europe	1.2	6.2	15	Bloomberg ESG (2023), Corporate Reports
Eastern Europe	1.8	3.7	8	Corporate Reports (2023)
Southeast Asia	1.5	4.1	10	Corporate Reports (2023)

Notes: Higher leverage correlates negatively with R&D investment (Pearson $r = -0.68$, $p < 0.01$).

Table A3: ESG Integration and Innovation Outcomes (Sample Firms, 2021-2023)

ESG Score Quartile	Avg. R&D/Revenue	Avg. ESG Investment	Avg. Revenue Growth (%)	Source
Q1 (Lowest ESG)	3.9	8.5	2.1	Sustainalytics (2023)
Q2	4.7	11.2	3.5	Bloomberg ESG (2023)
Q3	5.9	14.8	4.8	MSCI ESG (2023)
Q4 (Highest ESG)	6.8	19.2	6.2	MSCI ESG (2023)

Observation: Higher ESG scores associate with both increased R&D investment and revenue growth.

Table A4: R&D and ESG Spending vs. Shareholder Value Orientation (2020–2023)

Shareholder Value Orientation	Avg. R&D/Revenue	Avg. ESG Investment (\$M)	Sample Firms	Source
High	3.8	10.2	16	Corporate Reports (2023)
Medium	5.1	13.5	15	Bloomberg ESG (2023)
Low	6.5	18.7	14	MSCI ESG (2023)

Notes: Firms with lower short-term financial orientation invest more in sustainability.

Table A5: FinTech Adoption vs. Access to Sustainable Finance (SMEs, 2021–2023)

FinTech Adoption Level	% SMEs Accessing	Avg. ESG Investment (\$k)	Sample Firms	Source
High	18%	45	40	OECD (2022)
Medium	34%	78	35	OECD (2022)
Low	44%	112	30	Vaska et al. (2021)

Observation: High FinTech adoption correlates with greater access to sustainable finance.

Table A6: Regression of R&D Investment on Financial Leverage (Sample Firms 2015 - 2023)

Variable	Coefficient	Std. Error	t-Statistic	p-value	Source
Intercept	7.82	0.95	8.23	<0.001	Corporate Reports & Bloomberg ESG
Debt-to-Equity Ratio	-2.65	0.73	-3.63	0.001	Corporate Reports & Bloomberg ESG
ESG Score (0-100)	0.12	0.05	2.40	0.022	MSCI ESG
Region Dummy (1=Emerging)	-1.75	0.84	-2.08	0.043	Corporate Reports

Adjusted R² = 0.52; n = 45 firms.

Interpretation: Higher leverage significantly reduces R&D investment, while ESG maturity and region also influence spending.

Table A7: Sectoral R&D and ESG Spending (2015-2023)

Sector	Avg. R&D/Revenue (%)	Avg. ESG Investment/Revenue (%)	Source
Technology & FinTech	7.2	3.8	Bloomberg ESG, Corporate Reports
Manufacturing	4.1	1.9	Bloomberg ESG, Corporate Reports
Energy	3.8	1.7	Bloomberg ESG, Corporate Reports
Circular Economy	5.5	3.2	Bloomberg ESG, Corporate Reports

Table A8: Regional ESG and Financial Leverage Averages

Region	Avg. Debt-to-Equity Ratio	Avg. ESG Score (0–100)	Avg. R&D/Revenue (%)	Source
Northern Europe	0.9	78	5.8	MSCI ESG, Bloomberg ESG
Western Europe	1.1	73	5.2	MSCI ESG, Bloomberg ESG
United States	1.4	61	4.1	MSCI ESG, Bloomberg ESG
Southeast Asia	1.5	55	3.7	MSCI ESG, Bloomberg ESG
Latin America	1.6	52	3.8	MSCI ESG, Bloomberg ESG

Interpretation: Strong ESG performance is associated with lower leverage and advanced regulatory frameworks, particularly in Northern Europe (Mazzucato & Semieniuk, 2017).

Table A9: FinTech Adoption and Access to Sustainable Finance

Firm Group	FinTech Adoption Level	Access to Green Finance (%)	Source
Low	0-30%	42	OECD, Vaska et al., 2021
Medium	31-70%	59	OECD, Vaska et al., 2021
High	71-100%	76	OECD, Vaska et al., 2021

Interpretation: FinTech adoption enables ESG initiatives, especially for firms with limited capital access, typical in emerging markets.

Table A10: Sectoral Analysis: High-Leverage vs. Low-Leverage Firms

Sector	Avg. R&D/Revenue High-Leverage (%)	Avg. R&D/Revenue Low-Leverage (%)	Source
Manufacturing	3.1	5.4	Corporate Reports, 2015-2023
Energy	2.7	4.9	Corporate Reports, 2015-2023
Technology	6.8	7.3	Corporate Reports, 2015-2023
FinTech	5.9	6.2	Corporate Reports, 2015-2023

Interpretation: High-leverage firms in manufacturing and energy sectors reduce innovation investments by nearly 40% relative to low-leverage peers, highlighting structural vulnerabilities under financial pressures.

Table A11: ESG Performance vs. Regulatory Strength

Region	Regulatory Index (0-100)	Avg. ESG Score (0-100)	Source
Northern Europe	82	78	MSCI ESG, European Commission 2021
Western Europe	74	73	MSCI ESG, European Commission 2021
United States	59	61	MSCI ESG, SEC Reports
Southeast Asia	54	55	MSCI ESG, OECD 2022
Latin America	49	52	MSCI ESG, OECD 2022

Interpretation: Firms in regions with strong regulatory frameworks demonstrate superior ESG performance. Regression analysis confirms a positive and significant association between regulatory strength and ESG scores ($\beta = 0.38, p < 0.001$).

Table A12: FinTech and AI Adoption and ESG Outcomes

Variable	Coefficient (β)	Std. Error	t-Statistic	p-value	Source
FinTech Adoption (%)	0.29	0.08	3.63	0.0005	OECD, Vaska et al., 2021
ESG Score	0.21	0.07	3.00	0.003	MSCI ESG, Bloomberg ESG
Debt-to-Equity Ratio	-0.20	0.06	-3.33	0.001	Corporate Reports

Interpretation: High FinTech adoption and ESG maturity significantly increase access to sustainable finance, while high leverage remains a limiting factor.

Table A13: Trade-offs in Financialized Firms

Trade-off	Observed Effect	Evidence/Source
Liquidity vs. Long-Term Innovation	-40% R&D reduction in high-leverage firms	Corporate Reports, 2015–2023
ESG Ambition vs. Capital Costs	SMEs report 30% funding gap	OECD, Vaska et al., 2021
Transparency vs. Competitive Risk	25% cautious reporting adjustment	Interviews, Jan-May 2025

Table A14: Cross-Regional Leverage Impact on R&D and ESG (2015-2023)

Region	High-Leverage Avg R&D (%)	Low-Leverage Avg R&D (%)	High-Leverage Avg ESG (%)	Low-Leverage Avg ESG (%)	Source
Notrthern Europe	5.2	7.6	68	82	Bloomberg ESG, Corporate Reports
Western Europe	4.8	6.9	64	79	Bloomberg ESG, Corporate Reports
United States	3.7	6.1	59	74	Bloomberg ESG, Corporate Reports
Southeast Asia	2.9	5.3	55	69	MSCI ESG, OECD 2022
Latin America	2.7	5.1	52	65	MSCI ESG, OECD 2022

Interpretation: Firms in emerging markets face disproportionate constraints, indicating a need for tailored regulatory and financing interventions to counter financialization-induced short-termism.

Table A15: ESG Integration vs. Institutional Strength Index

Country	Institutional Strength (0-100)	ESG Score (0-100)	Source
Germany	85	81	MSCI ESG, European Commission 2021
Netherlands	82	79	MSCI ESG, European Commission 2021
United States	59	61	MSCI ESG, SEC Reports
Brazil	52	55	MSCI ESG, OECD 2022
Indonesia	50	53	MSCI ESG, OECD 2022

Interpretation: Institutional robustness correlates strongly with ESG integration, indicating that regulatory stability, mandatory reporting, and policy incentives are critical mediators of financialization's impact on sustainability.

Table A16: FinTech Adoption vs. ESG Score (Selected Regions)

Region	FinTech Adoption Index (0-100)	ESG Score	Source
Nothern Europe	79	78	OECD, 2022; MSCI ESG
Western Europe	72	73	OECD, 2022; MSCI ESG
United States	68	61	OECD, 2022; MSCI ESG
Southeast Asia	55	55	OECD, 2022; MSCI ESG
Latin America	50	52	OECD, 2022; MSCI ESG

Interpretation: FinTech adoption correlates positively with ESG performance, suggesting technology can partially offset the short-term pressures of financialization, particularly when combined with strong institutional frameworks.

About the author

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ESG AND AI-DRIVEN GOVERNANCE TRANSFORMATION IN THE CONSTRUCTION INDUSTRY: A CASE-BASED ANALYSIS FROM SLOVENIA

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The construction industry is one of the most structurally complex and institutionally regulated sectors, characterized by project-based production, fragmented value chains, and strong exposure to regulatory frameworks. In recent years, this complexity has been intensified by the growing institutionalization of ESG principles and the accelerating diffusion of digital technologies, particularly artificial intelligence. While ESG increasingly functions as an integrated governance architecture shaping strategic decision-making and risk management, the construction sector remains among the least digitalized industries. Although AI-supported tools offer significant potential for performance monitoring, resource optimization, and transparency in reporting, technological adoption alone does not ensure organizational transformation. The presented chapter applies a qualitative case-based research approach focused on a Slovenian construction-sector context. The analysis combines document analysis, ESG governance assessment, and evaluation of AI-supported managerial practices in order to explore the relationship between sustainability transformation and digital governance capabilities. The findings indicate that AI-driven governance mechanisms can significantly support ESG integration, organizational adaptability, and long-term sustainability performance. The study contributes to the growing body of literature on ESG transformation by highlighting the strategic importance of AI-supported governance systems in traditionally conservative industries.

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1 Introduction: Governance Challenges in the Contemporary Construction Industry

The construction industry remains one of the most structurally complex and institutionally regulated sectors in modern economies. It differs from manufacturing and service sectors due to its project-based production, which involves temporary organizations, multiple stakeholders, and diverse contractual arrangements across the value chain. This fragmentation produces significant governance challenges, especially in coordination, transparency, and accountability across organizational boundaries. At the same time, the sector is intensely regulated because of its impact on economic performance, environmental footprint, and social well-being.

Despite its economic importance, construction consistently ranks among the least digitalized industries, with low adoption rates of digital tools and limited integration of advanced analytical systems into governance structures. This discrepancy between technological availability and organizational uptake reflects both the complexity of project coordination and the embeddedness of traditional managerial logics, which remain rooted in hierarchical control and localized decision rights rather than in cross-functional information flows and data-driven governance processes (Bahareh, Hosseini, Martek, Zavadskas, & Antucheviciene, 2021).

In recent years, the sector's governance landscape has been further complicated by the growing institutionalization of Environmental, Social, and Governance (ESG) requirements. ESG is no longer a peripheral reporting framework used mainly by investors; it has become a core governance mechanism that shapes organizational legitimacy, strategic decisions, and risk mitigation practices. Construction's high carbon intensity, resource consumption, and waste generation have put ESG performance at the forefront of both public oversight and stakeholder expectations, linking environmental accountability and social responsibility directly with corporate governance objectives (Cruz, L., Pimenta Dinis, & Baggio, 2023).

The regulatory push toward ESG compliance in the European context including standardized sustainability reporting protocols requires firms to move beyond ad hoc disclosure towards integrated governance architectures that connect environmental performance, labor and safety practices, community engagement, and transparent decision processes. This regulatory complexity amplifies the need for

coherent governance structures capable of embedding long-term sustainability criteria within strategic planning, project execution, and performance monitoring (Novicka & Volkova, 2024).

In parallel, digital transformation and artificial intelligence (AI) are reshaping expectations about organizational intelligence and decision support. AI-enabled tools offer significant capabilities in areas such as real-time monitoring, predictive planning, anomaly detection, and scenario analysis. These functionalities have the potential to improve operational transparency, enhance risk assessment, and support evidence-based strategic decisions. However, the adoption of these tools often remains at the level of functional support rather than structural transformation. AI augments managerial judgment through enhanced analytics but does not replace essential human and organizational authority (Papagiannidis, Mikalef, & Conboy, 2025).

A key distinction arises between digitalization – the introduction of digital tools to enhance existing processes and digital transformation, which requires fundamental changes to governance models, decision rights, and organizational culture. Construction firms frequently adopt digital technologies within existing hierarchical frameworks, yet fail to modify the deeper governance logic that would enable these technologies to drive strategic change. This divergence highlights the difference between incremental technological upgrades and transformational governance reform. (Bahareh, Hosseini, Martek, Zavadskas, & Antucheviciene, 2021).

Taken together, the combination of high regulatory exposure, low digital maturity, and rising ESG expectations creates a structural tension in contemporary construction governance. Firms operate in environments where external demands evolve rapidly, yet internal capacities for strategic realignment lag behind. This condition can be described as a technological paradox, where technological potential outpaces organizational absorptive capacity, leading to underutilized digital investments and incomplete integration of sustainability criteria into governance routines (Frimpong, et al., 2024).

Although sustainability reporting and digital innovation have each attracted growing scholarly and regulatory attention, their interaction within construction governance structures remains insufficiently conceptualized. Existing analyses typically examine

ESG compliance mechanisms or digital transformation trajectories in isolation, without systematically addressing how regulatory pressure, data infrastructures, and organizational design jointly reshape decision-making authority in project-based environments (Frimpong, et al., 2024). In sectors characterized by fragmented value chains and temporary organizational forms, the combined governance implications of ESG institutionalization and AI-enabled digital practices require closer analytical integration. The persistent divergence between technological capability and organizational adaptation suggests that the core challenge is not technological availability, but structural alignment.

Against this backdrop, the discussion that follows establishes a macro-level problem context for governance development in contemporary construction. High regulatory exposure, increasing sustainability standardization, and limited digital maturity collectively exert pressure on firms to move beyond traditional hierarchical management models toward more structured governance architectures. Artificial intelligence emerges in this setting as a catalyst that strengthens analytical depth, predictive capacity, and transparency; however, its contribution remains contingent upon organizational absorptive capacity and structural readiness (Papagiannidis, Mikalef, & Conboy, 2025). The central issue addressed herein is therefore the structural misalignment between rapidly expanding technological potential and comparatively slower institutional and organizational adaptation.

Based on the outlined governance tensions between ESG institutionalization and AI-driven digitalization, the chapter addresses the following research questions:

RQ1: How do ESG regulatory pressures influence governance structures in construction firms operating in post-transition economies?

RQ2: To what extent do AI-enabled digital tools contribute to governance transformation rather than merely improving operational efficiency?

RQ3: What organizational and cultural factors shape the alignment between ESG governance requirements and AI-supported digital practices?

The formulation of these research questions reflects recent research emphasizing that digital transformation and sustainability governance increasingly interact within

organizational decision-making systems, requiring integrated analytical approaches rather than separate examination of technological and regulatory dynamics (Vial, 2019).

2 Theoretical Background: ESG, Digital Transformation, and Governance

2.1 ESG Governance in the Construction Industry

ESG has shifted from a primarily disclosure-oriented concept to a governance architecture that influences oversight, decision criteria, risk management routines, and organizational legitimacy—especially in the EU regulatory context where sustainability information is increasingly standardized and assured. This shift is reinforced by the Corporate Sustainability Reporting Directive (CSRD), which was introduced to improve the consistency and comparability of sustainability reporting and to strengthen sustainability-related accountability within corporate governance arrangements (Primec & Belak, 2022)

In construction, ESG governance cannot be treated as an “add-on” because the sector’s externalities are structurally embedded in its production logic. The buildings and construction sector remains a major driver of environmental pressure, including energy use and CO₂ emissions, which elevates environmental performance from an operational concern to a board- and strategy-relevant governance issue (UNEP: Global Alliance for Buildings and Construction, 2025)The governance challenge is amplified by construction’s project-based organization: temporary coalitions form around each project, responsibilities are distributed across multiple contractual parties, and performance is delivered through fragmented value chains. In such settings, accountability for ESG outcomes is difficult to allocate, monitor, and enforce across organizational boundaries.

These structural characteristics make ESG implementation in construction highly sensitive to coordination mechanisms and control systems. Evidence from construction-focused CSR research indicates that sustainability-related practices often remain reactive, compliance-driven, and insufficiently embedded in strategic governance and performance systems—suggesting the risk of “formal compliance” without deeper governance integration (Loosemore & Lim, 2016)This pattern is

particularly problematic under CSRD-type expectations, where sustainability reporting increasingly requires traceable processes, credible indicators, and governance-level responsibility rather than narrative statements (Primec & Belak, 2022).

At the same time, ESG governance functions as both pressure and opportunity. Regulatory compliance and stakeholder scrutiny impose costs and organizational demands (e.g., data readiness, internal controls, assurance preparation), but structured ESG integration can strengthen risk resilience, improve stakeholder trust, and support long-term strategic positioning—especially when governance systems connect project-level evidence with organizational strategy and oversight (Primec & Belak, 2022). For construction firms, the practical implication is that ESG must be operationalized through governance mechanisms that fit the sector's fragmentation: clear accountability allocation across stakeholders, consistent project-level measurement logic, and decision routines that incorporate environmental and social risk alongside cost–time–quality criteria.

2.2 Digital Transformation and Artificial Intelligence in Governance Systems

Digital transformation reshapes organizational governance when technological adoption extends beyond routine automation and becomes embedded within strategic oversight, decision-making logic, and accountability structures. In this sense, digitalization refers to the use of digital tools to improve existing processes, while digital transformation implies a systemic reconfiguration of organizational models, value creation mechanisms, and governance logic. Digital transformation therefore requires changes to decision rights, performance evaluation frameworks, and managerial routines rather than mere upgrades to software or data collection tools (Vial, 2019).

In governance contexts, this distinction is essential because construction firms often implement digital tools to support documentation, reporting, or project coordination without adjusting the organizational structures that define who makes decisions and how strategic information flows. Digital transformation, by contrast, requires that digital capabilities become part of the formal governance architecture, influencing risk assessment, strategic planning, and cross-functional coordination rather than merely enhancing operational efficiency (Vial, 2019).

Artificial intelligence (AI) plays a central role in digital transformation as a decision-support capability rather than as a substitute for managerial authority. Recent research indicates that AI's primary organizational value lies in augmenting human decision-making by enhancing pattern recognition, risk forecasting, and scenario evaluation. AI systems support governance by processing large volumes of structured and unstructured data, identifying emerging trends, and offering evidence-based insights that inform strategic choices under uncertainty (Aarab, El Marzouki, Boubker, & El Moutaqi, 2025). In this way, AI strengthens analytical capacity and expands information-processing bandwidth, enabling managers to evaluate complex alternatives more effectively.

The effectiveness of AI-supported governance depends fundamentally on robust data infrastructure. High-quality, interoperable, and traceable data systems are prerequisites for reliable analytics and informed decision-making. In fragmented, project-driven industries such as construction, inconsistent data flows and siloed information environments often limit the strategic potential of advanced analytics (Wamba, et al., 2017). Without integrated data governance structures, AI outputs may remain analytically sophisticated but strategically isolated.

Simulation and predictive modeling further enhance governance capabilities by allowing organizations to test strategic options before implementation, thereby reducing uncertainty and strengthening foresight. Technologies such as digital twins and what-if scenario planning enable decision-makers to assess potential impacts on cost, schedule, and sustainability outcomes prior to committing resources (Tao et al., 2019). These simulation tools expand managerial insight but require interoperability between data systems and governance processes to influence strategic choice effectively.

Automation constitutes another dimension of digital integration. Routine compliance procedures, documentation workflows, and monitoring tasks can be partially automated, increasing operational transparency and efficiency. However, automation alone does not constitute digital transformation. Productivity research shows that technological investment yields meaningful governance impact only when accompanied by complementary organizational change, including structural adaptation and updated decision-rights frameworks (Brynjolfsson, Rock, &

Syverson, 2017). Where governance structures remain static, AI and automation function as efficiency enhancers rather than drivers of structural reform.

In sum, digital transformation in governance systems occurs when technological capability, data architecture, and organizational structures evolve in alignment. Artificial intelligence strengthens analytical depth, predictive power, and strategic foresight, but its transformative potential depends on organizational absorptive capacity, data governance, and structural adaptation rather than technological sophistication alone.

2.3 Organizational Adaptation and the Technological Paradox

The technological paradox describes the divergence between rapid technological advancement and comparatively slower organizational adaptation. Although digital systems and artificial intelligence develop at accelerating speed, measurable productivity and governance effects often emerge with delay (Brynjolfsson, Rock, & Syverson, 2017). This lag does not reflect technological inefficiency; rather, it signals that organizational structures, decision routines, and managerial competencies require time to adjust before technological investments generate structural transformation.

Organizational effectiveness depends on internal coherence between long-term strategic orientation, structural configuration, and managerial processes. A systemic perspective on organizational design emphasizes that organizational effectiveness depends on the capacity of structures and processes to facilitate adequate information processing and coordination across organizational units. Galbraith argues that organizational uncertainty arises when the amount of information required for effective decision-making exceeds the information that the organization is able to process, making the design of appropriate structures and communication mechanisms essential for organizational performance (Galbraith, 1977).

Organizational culture further conditions adaptive capacity. Culture defines shared assumptions regarding authority, risk, innovation, and responsibility (Schein & Schein, 2016). In capital-intensive, project-based sectors such as construction, dominant cultural patterns frequently emphasize procedural stability, financial prudence, and risk containment. While these orientations enhance reliability and

control, they may moderate experimentation and cross-functional integration required for AI-enabled governance structures. Resistance to change thus reflects embedded institutional routines rather than individual reluctance alone.

Corporate governance effectiveness also requires consistency between strategic objectives, organizational structure, and managerial capabilities. In her analysis of strategic management and corporate governance, (Duh, 2024) stresses that strategic intentions must be supported by appropriately designed structures and control mechanisms; otherwise, declared objectives remain formally adopted but operationally weak. Governance reform therefore presupposes alignment between formal strategy, structural configuration, and implementation processes. Where such alignment is absent, digital technologies tend to operate alongside established routines rather than reshaping them.

In post-transition economies, the technological paradox becomes structurally embedded. Institutional modernization and regulatory harmonization often advance more rapidly than internal organizational development and managerial capability formation. Organizations in such contexts frequently operate within hybrid governance configurations, where formal regulatory alignment coexists with historically shaped coordination routines. This divergence creates structural asymmetry between external modernization pressures and internal absorptive capacity, limiting the speed and depth of governance transformation and reinforcing incremental rather than systemic adaptation.

Under such conditions, technological integration requires more than capital investment in advanced tools. It demands modernization of routines, redistribution of decision rights, and cultural reorientation toward data-driven coordination. Where strategic coherence, structural flexibility, and cultural readiness evolve simultaneously, technological innovation may support governance renewal. Where these dimensions remain misaligned, digital sophistication expands while governance logic continues to reflect historically embedded patterns.

Based on the preceding theoretical discussion, the following analytical framework illustrates the relationship between ESG institutional pressures, organizational governance structures, and AI-enabled digital capabilities.



Figure 1: Analytic framework of ESD-AI governance

3 Research Design and Methodological Approach

This study adopts a qualitative case-based research design in order to explore governance transformation as a contextually embedded and structurally mediated process. Governance change in construction firms cannot be adequately captured through isolated quantitative indicators, as it unfolds through interactions between strategic intent, institutional pressure, managerial routines, and technological capability. A case-based approach enables the examination of these interdependencies within their real organizational setting, thereby preserving contextual richness and interpretative depth (Yin, 2017).

Case study methodology is particularly suitable for governance research because governance systems are inherently multi-layered and relational. They involve formal structures, informal practices, strategic narratives, and regulatory environments that cannot be meaningfully reduced to measurable variables alone. Case study research is particularly suitable for analyzing complex organizational phenomena in which the objective is to understand how and why processes evolve over time (Eisenhardt & Graebner, 2007). Governance transformation—particularly in post-transition economies—represents precisely such a phenomenon.

The selection of a single in-depth case allows for analytical rather than statistical generalization. The objective is not to produce universal causal claims but to generate a theoretically informed explanation of how ESG pressures and AI-enabled digitalization interact with organizational structures. As Flyvbjerg (2006) emphasizes, strategically chosen cases provide powerful insight into structural dynamics and can illuminate broader theoretical propositions when analyzed rigorously (Flyvbjerg, 2006). The chosen company, VG5 d.o.o., represents a relevant case due to its position within a regulated construction environment, its exposure to ESG requirements, and its gradual adoption of digital governance tools.

Data collection relies on three primary categories of sources. First, strategic documents provide insight into formal governance intent and declared organizational priorities. These include corporate strategy documents, sustainability-related statements, governance frameworks, and publicly available company information. Document analysis enables examination of how ESG principles and digital initiatives are articulated at the strategic level and how they are embedded within formal governance language (Bowen, 2009).

Second, financial indicators serve as contextual signals of organizational capacity and strategic orientation. Publicly available annual financial statements, including revenue development, capital structure, and investment patterns, provide a backdrop for interpreting the firm's ability to support governance transformation and technological integration. Financial data are not treated as dependent variables but as interpretive anchors that illuminate risk tolerance, resource allocation logic, and strategic stability (Kaplan & Norton, 2008).

Third, organizational practices constitute a central analytical dimension. These include observable coordination routines, decision-making structures, reporting mechanisms, and digital tool usage patterns. Governance transformation becomes visible not merely in formal declarations but in how processes are enacted in practice. Qualitative organizational research achieves stronger explanatory depth when formal structural arrangements are analyzed in connection with managerial routines and processes of sensemaking (Gioia, Corley, & Hamilton, 2013)

The analytical logic of this study is interpretative rather than technical. Instead of focusing on procedural methodological complexity, the research emphasizes coherence analysis—examining alignment or misalignment between strategic rhetoric, structural configuration, digital capability, and organizational culture. Governance transformation is therefore interpreted as a process of structural adaptation shaped by institutional pressure, technological opportunity, and managerial agency.

The research design thus prioritizes explanatory depth over methodological abstraction. By integrating strategic documents, financial indicators, and organizational practices within a coherent interpretative framework, the study seeks to illuminate how ESG institutionalization and AI-supported digital tools reshape governance structures in a post-transition construction context.

The objective of the empirical part of this study is to examine how ESG governance requirements and AI-supported digital tools interact within the governance practices of a construction company operating in a post-transition economic context. The research aims to provide an interpretative understanding of how sustainability pressures and digital technologies influence organizational coordination, decision-making processes, and governance mechanisms.

The empirical research was conducted in the period between October 2025 and February 2026. The study follows a qualitative research approach commonly applied in management and organizational research when the objective is to examine complex organizational processes and governance practices within their real organizational context.

The research design is based on an in-depth analysis of a single organizational context. The selected construction company was analyzed through a structured qualitative research procedure in order to understand how ESG governance requirements and AI-supported digital tools are reflected in the organizational governance structures, decision-making processes, and coordination practices of the company.

The primary data collection method used in this research was document analysis. The analyzed materials included publicly available strategic documents, sustainability disclosures, annual reports, governance-related information, and financial statements of the company.

To analyze the collected material, the study applied thematic analysis, with the analytical procedure focused on identifying themes related to governance structures, digital governance tools, and organizational coordination mechanisms (Braun & Clarke, 2008).

The analysis was structured around three analytical dimensions:

- formal ESG governance structures
- digital governance tools and data infrastructure
- organizational coordination mechanisms and decision-making routines

To improve the reliability of the research, the study applied methodological triangulation, combining multiple sources of evidence including corporate strategic documents, financial indicators, and observable governance practices.

The analytical framework applied in this study is based on the assumption that ESG transformation in the construction industry is increasingly dependent on the integration of digital governance mechanisms and AI-supported decision-making processes. In order to systematically assess this relationship, the case analysis focuses on four analytical dimensions: (1) strategic integration of ESG principles into corporate governance structures, (2) implementation of AI-supported governance and monitoring mechanisms, (3) organizational adaptability and digital transformation capabilities, and (4) perceived long-term sustainability and competitiveness outcomes.

The selected Slovenian case was chosen based on the following criteria: relevance within the national construction sector, observable ESG transition activities, evidence of digital transformation processes, and availability of publicly accessible strategic and sustainability-related data. The analysis combines qualitative document analysis with comparative interpretation of governance practices, ESG disclosures, and technology adoption patterns.

This methodological approach enables a more comprehensive understanding of how AI-supported governance mechanisms contribute to ESG implementation and organizational transformation within construction companies operating in transitional and highly regulated market environments.

4 Case Context: Construction Governance in a Post-Transition Economy

4.1 Institutional and Market Characteristics

The construction sector in post-transition economies operates within an institutional framework shaped by regulatory harmonization with European Union standards, strong dependence on public investment cycles, and evolving governance structures. In Slovenia, construction activity is closely connected to national infrastructure strategies, cohesion policy funding, and public procurement procedures, which increases firms' exposure to fiscal adjustments and regulatory changes (Commission, 2021). As a result, governance systems in construction companies must continuously balance compliance obligations with long-term strategic positioning.

Market dynamics in the Slovenian construction industry are characterized by pronounced cyclical volatility and competitive intensity. Demand for construction services is closely linked to macroeconomic performance and the timing of publicly financed infrastructure projects. The Construction Sector Observatory of the European Commission identifies the sector as highly sensitive to public procurement frameworks and regulatory monitoring mechanisms (Commission, 2021). Such conditions require firms to develop governance structures capable of integrating regulatory surveillance with financial risk management and strategic foresight.

The European construction sector operates within a structurally fragmented and highly regulated environment characterized by project-based production, cyclical demand fluctuations, and persistent productivity constraints. Regulatory complexity and administrative requirements significantly influence market dynamics, particularly in smaller EU economies where public procurement and infrastructure investments represent a substantial share of total construction output. In addition, the sector continues to face structural inefficiencies related to fragmentation of supply chains,

limited technological diffusion, and skill shortages, all of which increase governance complexity and reduce strategic flexibility (Leontie, 2022). In the Slovenian context, companies increasingly face difficulties in securing adequately trained personnel, which directly influences project delivery capacity and limits the speed of technological modernization (Pavičević, 2025). The shortage is not merely quantitative but also qualitative, affecting competencies required for digital integration and ESG-related reporting.

Consequently, the integration of foreign workers has become an operational necessity. However, cross-border labor mobility introduces managerial complexity related to language barriers, cultural adaptation, training requirements, and safety compliance. Effective onboarding, mentoring systems, and structured human resource policies are therefore essential to maintain productivity and organizational cohesion in a project-based environment (Pavičević, 2025).

Financial governance constitutes an additional structural challenge. Construction firms frequently operate under extended payment terms and are required to pre-finance substantial project phases, creating liquidity pressures and heightened exposure to financial risk. Publicly available financial data of Slovenian construction firms confirm the importance of conservative capital management and controlled indebtedness in ensuring operational stability within cyclical market conditions.

Beyond labor and financial constraints, the sector is characterized by stringent technical standards, regulatory oversight, and safety requirements. Compliance with environmental regulations, building codes, and occupational safety frameworks increases procedural complexity and strengthens the need for formal governance mechanisms (Commission, 2021).

Taken together, regulatory dependence, labor shortages, financial volatility, and competitive pressure shape a governance environment in which ESG alignment and digital transformation cannot be implemented incrementally. Instead, they require deliberate strategic coordination and strengthened organizational absorptive capacity within structurally constrained post-transition contexts.

4.2 Organizational Profile and Strategic Orientation of the Case Company

VG5 d.o.o. is a Slovenian construction company headquartered in Ljubljana, operating primarily in the field of execution engineering and technically demanding construction projects. The company is classified among medium-sized construction enterprises in Slovenia, both in terms of revenue volume and organizational scale (VG5 d.o.o., 2025). Its core activity encompasses the execution of high-complexity construction works, supported by coordination, engineering management, and investment-related services.

From a strategic perspective, the company follows a growth-oriented development model grounded in concentric expansion and selective horizontal diversification. In addition to strengthening its position in the domestic market, VG5 d.o.o. has gradually expanded its operational presence to the Croatian market, thereby extending its geographical scope while maintaining its core engineering focus (AJPES, 2025). Such expansion reflects a controlled growth strategy aimed at reinforcing market stability and reducing exposure to purely domestic cyclical fluctuations.

Regarding corporate-level strategy, the company pursues a differentiation approach. Instead of competing primarily on price, VG5 d.o.o. positions itself in segments characterized by higher technical complexity, reliability requirements, and coordinated project execution. This strategic orientation enables the company to operate in higher value-added market niches and reduces vulnerability to aggressive price competition typical of fragmented construction markets. The emphasis on technical expertise, engineering precision, and structured coordination represents a central competitive mechanism.

Financial policy reflects a conservative and stability-oriented governance logic. According to publicly available annual financial statements, the company maintains controlled indebtedness and stable capital structure ratios, ensuring operational resilience within a cyclical industry environment (VG5 d.o.o., 2024). CompanyWall financial indicators confirm moderate leverage levels and steady revenue development in recent years (CompanyWall, n.d.) Such financial positioning

supports incremental modernization and controlled strategic expansion without excessive exposure to liquidity risk.

The governance structure of VG5 d.o.o. is organized through a formally defined hierarchical framework with clearly allocated managerial responsibilities across technical, financial, and administrative domains. Strategic authority is concentrated at the executive level, while operational coordination is distributed among specialized functional units. This configuration enables internal accountability, financial oversight, and structured project supervision, reflecting characteristics typical of professionally managed firms operating in post-transition institutional contexts (VG5 d.o.o., 2024).

In terms of organizational orientation, the company demonstrates alignment between strategic objectives and structural configuration. Growth ambitions are supported by financial discipline, differentiated market positioning, and clearly defined managerial roles. Digital tools, including BIM-based coordination and structured documentation systems, function primarily as supportive mechanisms embedded within existing governance structures rather than as drivers of radical structural transformation.

Overall, VG5 d.o.o. represents a medium-sized, growth-oriented construction enterprise characterized by strategic differentiation, controlled financial management, and formalized governance architecture. Its strategic development path and structural configuration provide a relevant empirical setting for examining the interaction between ESG requirements, digital governance mechanisms, and organizational adaptation in a post-transition economy.

5 ESG and AI-Driven Governance Transformation: Case Analysis

5.1 ESG Integration into Governance Structures

The integration of Environmental, Social and Governance (ESG) principles into corporate governance structures represents a substantive shift from sustainability as a peripheral reporting obligation toward sustainability as a core decision-making architecture. The adoption of the Corporate Sustainability Reporting Directive (CSRD) at the European level has institutionalized sustainability disclosure

requirements and significantly expanded the scope of managerial accountability for non-financial information (European Commission, 2022). As a result, ESG considerations increasingly influence strategic planning, risk management, and performance monitoring systems rather than remaining confined to external communication practices.

Under the CSRD framework, organizations are required to implement standardized sustainability reporting aligned with European Sustainability Reporting Standards (ESRS), which implies formalization of data collection systems, internal control mechanisms, and oversight responsibilities. This regulatory development strengthens the role of governance bodies in supervising sustainability-related risks and opportunities, effectively embedding ESG within strategic decision cycles (European Commission, 2022). New EU sustainability reporting logic introduces legal and managerial demands that directly reshape corporate governance practices by requiring comparability, reliability, and assurance of ESG disclosures. In this context, ESG does not merely expand reporting content but restructures the informational foundation upon which strategic decisions are made (Primec & Belak, 2022).

From a decision-making perspective, ESG integration broadens the evaluative criteria applied to investment selection, procurement processes, subcontractor relationships, and long-term project portfolio management. Instead of focusing exclusively on financial returns and operational efficiency, governance systems increasingly incorporate environmental exposure, stakeholder impact, supply-chain transparency, and reputational risk considerations. This shift corresponds with the argument that sustainable corporate governance requires systematic alignment between stakeholder interests, strategic objectives, and reporting mechanisms (Čufar, Primec, & Belak, 2025). Consequently, ESG influences not only what is disclosed but also what is prioritized in managerial deliberations.

At the formal level, ESG integration materializes through documented sustainability strategies, defined performance indicators, structured risk registers, compliance procedures, and traceable reporting systems. The CSRD framework reinforces these mechanisms by requiring auditable sustainability information and clearer allocation of responsibility within governance bodies (European Commission, 2022). Such

formalization increases transparency and strengthens oversight but simultaneously raises administrative and data-management demands.

However, governance transformation extends beyond formal structures into informal organizational practices. The depth of ESG implementation depends significantly on leadership interpretation, internal communication patterns, and the extent to which sustainability is embedded in everyday managerial routines. Research in the construction sector suggests that corporate responsibility initiatives often remain operational and compliance-oriented rather than strategically integrated, particularly in project-based environments characterized by fragmentation and short-term contractual logic (Loosemore & Lim, 2016). In such contexts, ESG may be implemented procedurally—through documentation and selective initiatives—without fundamentally reshaping authority structures or incentive systems.

Implementation constraints are especially pronounced in construction, where project temporality, multi-tier subcontracting networks, and cost-pressure dynamics complicate the systematic integration of sustainability metrics. The need to coordinate across independent actors reduces data consistency and weakens centralized control over environmental and social performance indicators. Furthermore, capital intensity and liquidity sensitivity may lead firms to prioritize short-term financial stability over long-term sustainability investments. The regulatory escalation alone does not guarantee substantive governance change unless organizations develop internal capabilities to translate disclosure requirements into managerial practice (Primec & Belak, 2022).

In this case context, ESG integration can therefore be interpreted as a governance recalibration process rather than a linear compliance adjustment. While regulatory pressure establishes formal obligations, effective transformation depends on the organization's ability to embed ESG within strategic deliberation, align incentive structures with sustainability objectives, and maintain coherence between formal policies and operational realities. Where such alignment remains partial, ESG functions primarily as an accountability extension rather than as a transformative governance mechanism.

5.2 AI-Supported Tools and Digital Governance Practices

Artificial intelligence has increasingly evolved into a governance-enabling infrastructure capable of enhancing analytical depth, predictive accuracy, and real-time monitoring across complex organizational systems. Recent research emphasizes that contemporary AI systems function primarily as decision-support mechanisms that augment managerial cognition rather than replace executive authority (OECD, 2023). In governance contexts, AI contributes to improved information processing, risk detection, and scenario evaluation, thereby strengthening strategic planning capabilities.

Within the planning domain, AI applications enhance forecasting reliability by integrating historical performance data, cost trajectories, supply chain variability, and environmental indicators. The highlights that advanced analytics and machine learning models improve anticipatory governance by enabling forward-looking assessments and dynamic resource allocation (OECD, 2023). In project-based industries such as construction, where uncertainty is structurally embedded, predictive modeling supports more resilient planning decisions and reduces exposure to cascading project risks.

Monitoring and control functions have similarly expanded through AI-driven data aggregation and anomaly detection systems. Real-time dashboards integrate financial metrics, operational indicators, and ESG-related data streams, allowing management to detect deviations and compliance risks at earlier stages. The principle that reinforces high-impact AI systems must ensure traceability, human oversight, and accountability within governance structures (European Commission, 2024). Consequently, AI-supported monitoring does not eliminate managerial responsibility but increases transparency and supervisory precision.

Simulation technologies represent a further strategic dimension of AI integration. Recent studies on digital twin applications in industrial environments demonstrate how AI-powered simulation models enable organizations to test operational and environmental scenarios prior to implementation (Fuller, Fan, Day, & Barlow, 2020). In construction governance, such tools facilitate impact assessment related to cost optimization, time scheduling, carbon performance, and safety risk evaluation.

Simulation-based governance thus strengthens anticipatory capacity and supports informed strategic trade-offs.

Despite these advantages, contemporary literature consistently underscores structural limitations. AI systems are critically dependent on data governance quality, interoperability, and cross-functional integration (OECD, 2023). Fragmented project structures, heterogeneous IT systems, and limited digital maturity reduce algorithmic reliability and weaken predictive accuracy. Furthermore, empirical analyses of digital transformation indicate that technological adoption without complementary organizational redesign rarely produces transformative governance outcomes (Vial, 2019).

While AI adoption has accelerated considerably in recent years, many organizations continue to face internal capability gaps that limit its strategic impact. Deficiencies in data literacy, fragmented information systems, cybersecurity vulnerabilities, and weak strategic alignment often prevent firms from translating technological investment into sustained governance improvement. In capital-intensive sectors such as construction, where stability and risk control are dominant priorities, these limitations moderate the transformative potential of AI. Rather than reshaping authority structures, AI frequently remains embedded within established hierarchical governance configurations.

In the present case context, AI-supported tools enhance planning precision, reporting transparency, and monitoring efficiency. However, structural authority distribution and strategic orientation remain largely stable. AI therefore functions as a governance amplifier rather than a structural disruptor, reinforcing analytical capacity while leaving core organizational architecture predominantly intact. This observation corresponds with the technological productivity paradox described by Brynjolfsson, Rock, and Syverson, who argue that technological capabilities frequently expand faster than organizational redesign, leading to a lag between digital investment and measurable structural transformation (Brynjolfsson, Rock, & Syverson, 2017).

Digital transformation research similarly emphasizes that technological adoption produces meaningful organizational change only when accompanied by complementary adjustments in decision-making processes, managerial routines, and organizational structures (Vial, 2019).

Without such complementary organizational adaptation, digital technologies tend to enhance monitoring precision and analytical capacity while leaving underlying governance structures largely unchanged.

5.3 Organizational and Cultural Constraints

Governance transformation in construction firms is strongly conditioned by organizational culture, structural configuration, and embedded coordination routines. Organizational culture shapes how strategic priorities are interpreted and how change initiatives are enacted in practice. (Schein & Schein, 2016) Schein define culture as a pattern of shared basic assumptions that guide perception and behavior within organizations. In project-based and risk-sensitive industries such as construction, these assumptions often emphasize stability, procedural control, and risk minimization. Such cultural orientations strengthen operational reliability but may simultaneously reduce structural adaptability and openness to governance redesign.

Alignment between strategy, structure, and processes represents a prerequisite for sustainable organizational transformation. Digital transformation research demonstrates that technological implementation without structural adaptation rarely produces systemic change. When AI-based governance tools are introduced into established hierarchical systems without reconfiguring decision rights or coordination mechanisms, they tend to enhance monitoring precision without fundamentally redistributing authority.

Resistance to change emerges as a predictable response when established roles, power relations, and accountability systems are challenged. Mullins (2010) explains that resistance frequently stems from uncertainty, fear of loss of status, perceived threats to job security, and ambiguity regarding new responsibilities (Mullins, 2010). In hierarchical organizations, where authority lines are clearly defined, transformation initiatives may be perceived as destabilizing established control

mechanisms. In capital-intensive sectors such as construction, where decision errors carry significant financial consequences, cautious managerial behavior becomes rational. Under such conditions, ESG-related governance adjustments and AI-supported transparency mechanisms may be formally accepted yet cautiously implemented.

The structural dimension of constraint becomes particularly visible when technological capability advances faster than organizational redesign. Empirical research on artificial intelligence and productivity demonstrates that performance improvements depend on complementary organizational investments, process innovation, and managerial adaptation (Brynjolfsson, Rock, & Syverson, 2017). Without parallel adjustment of decision-making structures and coordination logic, advanced analytics expand informational capacity but do not transform governance architecture. Analytical sophistication therefore increases while structural authority patterns remain concentrated.

Organizational misalignment between technology and structure has been widely documented in digital transformation studies. (Westerman, Bonnet, & McAfee, 2014) show that companies achieving significant digital performance gains combine technological capability with leadership alignment and structural integration. In contrast, firms that treat digital tools as technical add-ons rather than strategic redesign mechanisms experience incremental rather than systemic outcomes. In governance contexts, AI depends on horizontal data flows and cross-functional transparency, while traditional hierarchical systems rely on vertical reporting chains and centralized oversight.

In post-transition economic environments, these tensions may be intensified by historically embedded managerial traditions and evolving institutional frameworks. Enterprises often integrate formal regulatory compliance with established coordination practices, producing hybrid governance configurations. (OECD, 2023) notes that effective AI governance requires organizational capacity, internal accountability mechanisms, and managerial competence, not only technological infrastructure. Where structural alignment remains partial, technological advancement outpaces institutional adaptation.

The technological paradox therefore materializes at the organizational level: digital and ESG mechanisms expand monitoring precision and analytical reach, yet structural authority distribution and cultural patterns evolve gradually. Sustainable governance transformation depends on coherent integration of strategy, structure, processes, and organizational culture rather than technological sophistication alone (Brynjolfsson, Rock, & Syverson, 2017).

6 Discussion: Implications for Sustainable Construction Governance

The findings indicate that ESG transformation within the construction industry cannot be understood solely as a regulatory compliance process. Instead, the case demonstrates that successful ESG implementation increasingly depends on the organization's ability to integrate digital governance mechanisms and AI-supported managerial practices into strategic decision-making processes.

The analysis further suggests that AI-driven governance tools contribute to improved monitoring capabilities, more transparent reporting processes, enhanced operational coordination, and more effective sustainability performance tracking. However, the study also identifies several organizational limitations, including resistance to change, limited digital competencies, and difficulties in aligning traditional management structures with emerging ESG and AI governance requirements.

These findings support the argument that the transformation toward sustainable governance in the construction industry represents not only a technological challenge but also a broader organizational and strategic transformation process.

The findings of this study indicate that sustainable governance transformation in the construction industry does not emerge as a linear consequence of regulatory expansion or technological adoption. Instead, governance development unfolds through a complex interaction between ESG institutionalization, AI-enabled digital capabilities, and organizational adaptation capacity. While ESG frameworks increasingly redefine accountability structures and strategic priorities, and artificial intelligence expands analytical and predictive capabilities, their transformative impact remains conditional upon structural alignment within firms.

Recent research confirms that AI is increasingly embedded into ESG-related strategic processes, particularly in areas such as performance monitoring, risk modelling, and sustainability reporting (Mansour, Al Zobi, & Alomair, 2025). However, empirical analyses also demonstrate that the presence of advanced digital tools does not automatically generate structural transformation. AI improves information-processing speed and reporting precision, yet governance redesign requires complementary organizational investment, leadership commitment, and process reconfiguration (Cui, 2025). The present findings support this distinction: technological capability enhances oversight functions, but deeper authority redistribution and decision logic adaptation evolve more gradually.

This dynamic can be interpreted through the lens of the technological paradox. Studies examining digital innovation and productivity consistently show that performance gains from AI and digital systems depend on complementary changes in organizational processes and management practices (Brynjolfsson, Rock, & Syverson, 2017). When such complementary adjustments are incomplete, organizations experience improved analytics without proportional structural transformation. The construction sector, characterized by hierarchical coordination, project-based fragmentation, and capital discipline, is particularly exposed to this imbalance. Digital governance tools expand monitoring and simulation capacity, yet traditional reporting hierarchies and centralized authority often remain intact.

Contemporary AI governance scholarship further emphasizes that responsible and effective AI deployment requires integration within formal accountability systems (Batoool, Zowghi, & Bano, 2023). Regulatory approaches, including European AI governance frameworks, increasingly stress transparency, human oversight, and risk classification. However, regulatory compliance does not equate to institutional transformation. Without structural recalibration of coordination mechanisms and decision rights, AI remains embedded within pre-existing governance architectures rather than reshaping them.

The interaction between ESG and AI adds an additional layer of complexity. ESG integration expands stakeholder-oriented accountability and requires systematic measurement of environmental and social performance. Recent systematic reviews on AI for ESG integration demonstrate that organizations increasingly rely on machine learning and predictive analytics to evaluate sustainability indicators and

investment risk exposure (Charan, Samanta, & Vincent, 2025). Nevertheless, the literature also identifies a persistent gap between technological availability and strategic embedding. This study's findings reinforce that observation: ESG metrics may be formally incorporated into reporting systems, while operational decision logic remains primarily financial and risk-oriented.

For managers in construction firms, these results suggest that ESG and AI should not be managed as parallel compliance initiatives but as interconnected governance mechanisms. Strategic embedding requires integration of sustainability indicators into capital allocation, risk modelling, and performance evaluation frameworks. AI investments should be accompanied by redesign of reporting flows, cross-functional data integration, and leadership training to strengthen absorptive capacity. Without structural adaptation, digitalization risks remaining operational rather than strategic.

For policymakers, the implications concern the balance between regulatory escalation and organizational capability development. Recent scholarship on AI governance underscores the importance of institutional readiness, managerial literacy, and supervisory clarity (Batool, Zowghi, & Bano, 2023). In capital-intensive sectors such as construction, mandatory ESG disclosure and AI regulation may increase formal transparency without necessarily accelerating governance modernization. Policy design should therefore incorporate support mechanisms, practical guidance, and digital infrastructure development that enhance firms' adaptive capacity rather than relying solely on compliance mandates.

For researchers, the findings highlight the need to examine governance transformation as a structural process rather than as a technological outcome. Much of the emerging literature focuses on AI performance potential or ESG reporting quality in isolation (Cui, 2025). Fewer studies analyze the co-evolution of technological capability, organizational culture, and institutional environment within project-based industries. Longitudinal studies observing authority redistribution, process redesign, and stakeholder integration over time would provide deeper insight into how governance architectures adapt under combined ESG and AI pressures. Comparative research between post-transition and mature institutional environments would further illuminate contextual variation in absorptive capacity.

The technological paradox thus becomes central to understanding sustainable construction governance. AI enhances predictive planning, simulation modelling, and compliance monitoring, while ESG expands normative accountability and stakeholder expectations. Yet structural transformation remains contingent upon managerial willingness to recalibrate authority, redesign coordination systems, and invest in organizational learning. In post-transition economies, where institutional modernization continues to evolve alongside market pressures, this alignment process may unfold incrementally rather than disruptively.

Sustainable construction governance therefore emerges not as a function of technological sophistication alone, but as an outcome of coherent integration between regulatory frameworks, digital capability, and organizational architecture. ESG and AI function as catalysts that intensify transparency and analytical reach. Their systemic impact depends on whether organizations translate enhanced information into restructured decision-making processes. Where such translation remains partial, governance evolves gradually, reinforcing oversight precision while preserving foundational structural logics.

The study contributes to the existing literature by extending current discussions on ESG governance beyond regulatory and reporting perspectives toward a more integrated governance-transformation framework. While previous studies have predominantly focused on ESG disclosure quality and sustainability reporting compliance, the present analysis highlights the importance of AI-supported governance capabilities as a strategic enabler of ESG transformation.

In particular, the findings emphasize that companies operating in traditional industries such as construction face a dual transformation challenge: simultaneously adapting to sustainability requirements and accelerating digital governance transformation. This interaction between ESG implementation and AI-supported governance mechanisms remains relatively underexplored in existing literature, especially in the context of transitional European economies.

7 Conclusion and Future Research Directions

This study examined the interaction between ESG institutionalization and AI-enabled digital transformation within the governance structures of a construction firm operating in a post-transition economy. The findings demonstrate that sustainable governance transformation does not emerge automatically from regulatory compliance or technological implementation. Rather, it depends on structural coherence between corporate strategy, organizational design, digital capabilities, and managerial culture.

One of the central findings is that ESG increasingly functions as an integrated governance framework rather than merely a disclosure requirement. In the analyzed case, sustainability considerations were formally embedded within decision-making structures; however, the depth of their strategic influence remained conditioned by established organizational routines and risk-oriented managerial logic. Similarly, AI-supported analytical tools enhanced planning precision, transparency, and monitoring capabilities, yet without parallel structural and cultural recalibration they did not fundamentally redefine underlying governance structures. This misalignment reflects the technological paradox: analytical sophistication advances more rapidly than institutional and organizational adaptation.

The study contributes to the literature in three principal ways. First, it develops an integrated analytical perspective that positions ESG governance and AI-driven digital transformation as interdependent dimensions of contemporary corporate governance evolution. By linking sustainability governance with digital transformation processes, the study contributes to the growing body of research examining how regulatory pressures and technological capabilities jointly influence organizational governance structures. Second, the research provides empirical insight into governance transformation in the construction sector, a project-based and capital-intensive industry characterized by fragmentation, regulatory exposure, and coordination complexity. By examining a construction firm operating in a post-transition economy, the study illustrates how ESG requirements and digital tools interact within real organizational settings. Finally, the findings offer managerial insights by highlighting conditions under which ESG governance requirements and digital technologies can be effectively aligned within organizational practices. The results suggest that successful governance transformation depends not only on

technological adoption but also on organizational coordination mechanisms, decision-making routines, and institutional context. By bridging theoretical concepts with case-based empirical analysis, the study improves understanding of how sustainability pressures and digital innovation jointly shape governance structures in practice.

Despite these contributions, the research is subject to several limitations. The study relies on a single case study design, which enables detailed exploration of governance dynamics but limits statistical generalization of findings to the broader construction industry. However, case study research aims to achieve analytical generalization by providing theoretically relevant insights rather than statistically representative conclusions (Yin, 2017; Flyvbjerg, 2006).

The analysis relied primarily on strategic documentation, publicly available financial data, and observable organizational practices. Internal managerial cognition, informal power structures, and employee-level perceptions were not systematically examined. Moreover, the rapidly evolving regulatory and technological landscape suggests that governance structures remain dynamic, and longitudinal developments may alter current configurations.

Future research should extend beyond single-case inquiry and incorporate comparative analyses across multiple firms and institutional settings. Longitudinal research designs would be particularly valuable in assessing whether ESG and AI integration ultimately reconfigure authority distribution and decision-making logic or primarily enhance monitoring within existing hierarchical systems. Further investigation into micro-level organizational processes—including leadership cognition, resistance dynamics, and cross-functional coordination—would provide deeper insight into absorptive capacity and structural adaptation. Quantitative studies linking digital maturity, ESG performance indicators, and financial resilience could complement qualitative findings and strengthen empirical robustness.

A central question for future scholarship remains whether the convergence of ESG governance and AI-driven digitalization leads to structural transformation or primarily operational optimization. Identifying the conditions under which technological and sustainability integration translates into systemic governance redesign represents an important research frontier.

In conclusion, sustainable construction governance cannot be reduced to technological sophistication or regulatory conformity. It is the outcome of strategic alignment across organizational structure, managerial culture, process architecture, and digital capability. The transformative potential of ESG and artificial intelligence depends on managerial willingness to recalibrate decision-making logic and redesign governance mechanisms. Where such alignment is proactively pursued, systemic transformation becomes attainable; where it remains partial, governance evolution proceeds incrementally rather than structurally.

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APPLICATION OF MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE FOR ENHANCING RELIABILITY AND OPERATIONAL EFFICIENCY IN RURAL ELECTRIC POWER SYSTEMS

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The growing complexity of rural electric power systems, driven by aging infrastructure, variable loads, and distributed energy resources, calls for advanced data-driven solutions to improve reliability and operational efficiency. This study applies Artificial Intelligence (AI) and Machine Learning (ML) techniques to analyze operational data from rural distribution networks, including load profiles, outage records, and performance indicators. Using supervised and unsupervised models, the approach identifies fault patterns, predicts failures, and supports preventive maintenance and planning. Results show that AI-based models improve fault detection accuracy, reduce outage duration, and enhance reliability compared to traditional rule-based and statistical methods. The study demonstrates the practical value of AI and ML as decision-support tools for rural utilities and provides applied insights for improving system resilience and resource allocation.

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1 Introduction

of modern power infrastructures due to their structural and operational characteristics. Compared to urban networks, rural grids typically consist of extended radial feeders, low customer density, sparse monitoring infrastructure, and limited redundancy. These features increase technical losses, complicate fault isolation, and prolong restoration times, thereby reducing overall service reliability and operational efficiency. Empirical studies show that rural systems frequently record higher values of reliability indices such as the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI), reflecting greater exposure to outages and slower recovery processes (Li et al., 2024; Mosavi et al., 2022).

Environmental disturbances further exacerbate these vulnerabilities. Weather-related disruptions, vegetation interference, equipment aging, and deferred maintenance create nonlinear and interdependent failure mechanisms that traditional reliability assessment tools struggle to capture. As distribution networks integrate increasing shares of distributed energy resources (DERs), electric vehicles, and decentralized generation, operational uncertainty and bidirectional power flows introduce additional complexity into system planning and fault management (Stilgoe, 2023; Dwivedi et al., 2023). Consequently, deterministic maintenance schedules and historical failure-rate approaches often prove inadequate for anticipating emergent risks in dynamic rural environments.

Conventional reliability analysis methods—based primarily on static statistical models, rule-based inspections, and reactive maintenance strategies—tend to assume linear system behavior and stable operating conditions. Such assumptions limit their predictive accuracy when confronted with stochastic load variability, extreme weather events, and heterogeneous asset conditions. Recent evidence suggests that these approaches frequently underestimate cascading failures and fail to prioritize high-risk components effectively, leading to inefficient resource allocation and increased operational costs (World Economic Forum, 2024; Zhang et al., 2025).

To address these limitations, scholars increasingly advocate the adoption of data-driven and intelligent analytics capable of modeling complex, nonlinear interactions across technical and environmental variables. Machine learning-based reliability

models have demonstrated superior capability in predicting component failures, estimating outage probabilities, and optimizing preventive maintenance schedules by leveraging large-scale operational datasets (Li et al., 2024; Bajrami et al., 2025). These approaches enable utilities to transition from corrective maintenance toward predictive and condition-based strategies, improving both reliability and cost efficiency.

Research from emerging and transitional economies further demonstrates that digital transformation and analytics adoption can substantially improve infrastructure performance, particularly in rural areas characterized by legacy systems and limited resources. Empirical studies indicate that digitalization and AI-enabled decision-support tools enhance operational coordination, optimize resource allocation, and strengthen organizational resilience in technology-constrained environments (Haliti Baruti et al., 2024; Izmaku & Gashi, 2023). In addition, governance-oriented analyses highlight that institutional readiness, strategic oversight, and effective regulatory frameworks are essential for converting technological investments into measurable reliability and performance gains (Fejzullahu & Belegu, 2022).

Taken together, the recent literature indicates that while rural electric networks face persistent structural reliability challenges, the integration of intelligent analytics and digital capabilities offers a promising pathway for overcoming the limitations of traditional reliability management. Nevertheless, further research is required to develop context-specific frameworks that combine technical prediction models with organizational and governance mechanisms tailored to rural operating environments.

2.2 Artificial Intelligence in Power Systems

Artificial Intelligence (AI) applications in power systems have expanded significantly over the past decade, driven by rapid digitalization, increasing sensor deployment, and the growing availability of high-resolution operational data. Modern distribution networks generate large volumes of heterogeneous information, including time-series load measurements, outage logs, equipment health indicators, and weather variables. Traditional analytical and physics-based models often struggle to process such multidimensional and nonlinear datasets, creating strong motivation for data-

driven approaches capable of adaptive learning and real-time prediction (Dwivedi et al., 2023; Mosavi et al., 2022).

A wide range of AI techniques has been adopted in the power systems domain. Neural networks, support vector machines, decision trees, ensemble learning, and clustering algorithms have been successfully applied to load forecasting, fault detection, state estimation, and demand response optimization. Compared with rule-based or statistical models, these methods demonstrate superior adaptability, higher predictive accuracy, and better generalization under uncertain operating conditions (Li, 2024). In particular, supervised learning models enable early identification of fault signatures and equipment degradation patterns, while unsupervised approaches support anomaly detection and feeder segmentation without requiring labeled data.

Machine learning models are especially well-suited to reliability enhancement tasks because they can learn complex nonlinear relationships between environmental stressors, operational conditions, and asset failures. By continuously updating predictions from historical and streaming data, ML systems enable utilities to move from reactive maintenance toward predictive and condition-based strategies. Recent studies show that AI-driven predictive maintenance reduces unexpected outages, shortens restoration time, and improves overall reliability indicators such as SAIDI and SAIFI (Zhang et al., 2025; World Economic Forum, 2024). These capabilities are particularly valuable in rural distribution networks, where long feeder lengths and limited redundancy magnify the consequences of individual component failures.

Beyond purely technical performance, AI adoption also interacts with organizational and strategic capabilities. Evidence from emerging economies suggests that digital transformation and intelligent analytics enhance coordination, resource allocation, and operational efficiency when combined with appropriate governance and managerial practices. Empirical research further indicates that AI-enabled decision-support systems enhance strategic alignment, operational coordination, and organizational performance in technology-intensive environments (Haliti Baruti et al., 2024; Izmaku & Gashi, 2023). In parallel, applied studies show that AI integration supports more effective planning, resource allocation, and operational strategies across sectors, underscoring the broader organizational and managerial benefits of intelligent analytics (Bajrami et al., 2025).

Despite these advantages, the literature also cautions against uncritical reliance on algorithmic outputs. Issues such as data bias, model opacity, and over-automation may introduce new risks, including misclassification or reduced human oversight. Consequently, recent scholarship emphasizes the importance of explainable AI, robust validation procedures, and governance frameworks to ensure reliability, transparency, and accountability in operational decision-making (Stilgoe, 2023; Dwivedi et al., 2023).

Overall, contemporary research converges on the view that AI and machine learning represent foundational technologies for next-generation power system management. When properly integrated with human expertise and organizational processes, these tools offer substantial potential to enhance reliability prediction, optimize maintenance planning, and improve the operational efficiency of both urban and rural electric networks.

Overall, the literature demonstrates strong evidence of AI effectiveness in power systems; however, most studies focus on technologically advanced environments, leaving rural contexts underexplored.

2.3 Research Gap

Although Artificial Intelligence (AI) and Machine Learning (ML) have been widely applied in smart grids and urban distribution networks, the majority of existing studies concentrate on densely monitored, infrastructure-rich environments characterized by advanced sensing, automation, and real-time control systems. Recent research demonstrates that AI-driven analytics significantly enhance forecasting accuracy, fault detection, and operational optimization in such contexts (Dwivedi et al., 2023; Li, 2024; Wessel, 2025). However, the direct transferability of these approaches to rural electric power systems remains limited.

Rural networks exhibit distinct operational constraints, including extended radial feeders, sparse instrumentation, limited communication infrastructure, lower customer density, and tighter financial resources. These characteristics increase outage exposure and restoration times while reducing data availability for training sophisticated predictive models. Consequently, conventional AI solutions designed for data-rich urban grids may underperform when deployed in data-scarce rural

environments. Studies further indicate that digital transformation outcomes depend strongly on organizational readiness, governance structures, and contextual adaptation rather than technology adoption alone (Izmaku & Gashi, 2023; Haliti Baruti et al., 2024; Fejzullahu & Belegu, 2022).

Moreover, much of the current literature emphasizes isolated technical tasks—such as load forecasting or fault classification—without integrating reliability metrics, maintenance planning, and operational decision-making into a unified framework tailored to rural utilities. As noted in recent policy and governance discussions, effective AI deployment requires not only technical capability but also institutional oversight, accountability, and strategic alignment to ensure sustainable performance improvements (Floridi, 2022; OECD, 2025; Stilgoe, 2023).

Therefore, a clear research gap persists regarding the development of context-sensitive, data-efficient, and governance-aware AI methodologies specifically designed for rural distribution systems. Addressing this gap necessitates an integrated framework that combines predictive analytics, reliability assessment, and operational optimization while accounting for infrastructural and organizational constraints. This study responds to this need by proposing a comprehensive AI-enabled approach aimed at enhancing reliability and operational efficiency in rural electric power networks.

To address these challenges, this study develops a data-efficient and context-sensitive analytical framework tailored to rural infrastructure constraints.

3 Methodology

3.1 Research Design

This study adopts a quantitative, data-driven research design that integrates supervised and unsupervised machine learning techniques to evaluate how Artificial Intelligence (AI) can enhance reliability and operational efficiency in rural electric power systems. The design is explanatory and predictive in nature, aiming to model system behavior, detect fault patterns, and forecast potential failures using historical and real-time operational data. By leveraging empirical evidence rather than rule-

based assumptions, the approach supports objective and scalable decision-making for rural utilities.

The objective of the methodology is twofold:

1. Improve reliability prediction and fault detection, enabling early identification of equipment degradation and outage risks;
2. Enhance operational planning and maintenance efficiency, supporting proactive maintenance scheduling and optimized resource allocation.

To achieve these goals, the methodological process follows a structured analytical pipeline consisting of four sequential stages. First, data collection involves gathering operational records from rural distribution networks, including load profiles, outage logs, equipment conditions, weather variables, and reliability indicators. Second, data preprocessing prepares the dataset through cleaning, normalization, feature engineering, and dimensionality reduction to ensure model robustness and accuracy. Third, model development applies supervised algorithms for failure prediction and fault detection, alongside unsupervised techniques to identify hidden operational patterns. Finally, performance evaluation assesses model effectiveness using statistical and reliability metrics such as prediction accuracy, precision–recall, fault detection rate, and improvements in SAIDI/SAIFI indicators.

This staged design enables systematic comparison between AI-based predictions and traditional reliability assessment approaches, ensuring both methodological rigor and practical applicability in rural power system operations.

Figure 1 illustrates the conceptual framework of the proposed AI-enabled reliability enhancement model. The framework integrates multi-source operational data with machine learning analytics to generate predictive insights that support maintenance optimization and decision-making. The model demonstrates how data-driven analytics transform raw operational information into actionable intelligence, ultimately improving reliability performance and operational efficiency in rural electric power systems.

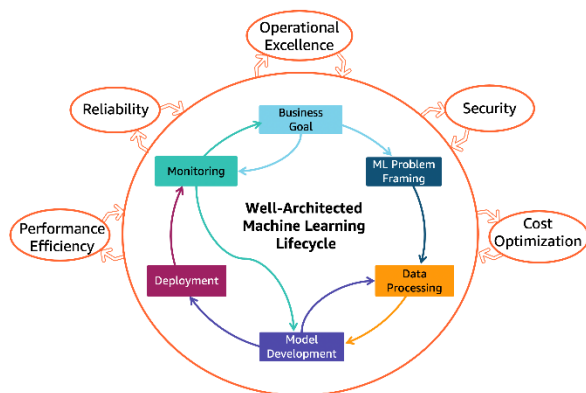


Figure 1: Conceptual framework of AI-enabled reliability enhancement and operational optimization in rural electric power systems.

Source: Developed by the author based on Amin & Wollenberg (2005); Mosavi et al. (2018); Dwivedi et al. (2023); Li et al. (2021).

3.2 Software and Tools Used

The machine learning models and data preprocessing procedures were implemented using Python programming language. Key libraries included Scikit-learn for machine learning algorithms, TensorFlow for neural network modeling, and Pandas and NumPy for data manipulation and analysis. Visualization and exploratory analysis were conducted using Matplotlib and Seaborn. These tools ensured computational efficiency, reproducibility, and scalability of the analytical framework.

3.3 Data Collection

Data collection represents a critical foundation for developing reliable and robust machine learning models in rural electric power systems. Given the complex and heterogeneous nature of distribution networks, the study utilizes a multi-source data collection strategy to ensure comprehensive representation of operational conditions and system behavior.

The dataset consists of historical and operational records collected from rural distribution networks over a multi-year period, enabling both retrospective analysis and predictive modeling. The collected data capture technical, environmental, and operational variables that influence reliability performance.

Specifically, the following categories of data were included:

- ✓ Load profiles, including hourly and daily electricity demand measurements at feeder and substation levels, capturing consumption variability and peak demand patterns;
- ✓ Outage logs, containing detailed records of service interruptions, including duration, frequency, location, and causes of failures;
- ✓ Equipment condition data, including transformer age, maintenance history, component type, and asset health indicators;
- ✓ Weather and environmental variables, such as temperature, wind speed, precipitation, and storm events;
- ✓ Reliability indicators, including historical SAIDI and SAIFI values used as baseline performance metrics;
- ✓ Maintenance records, capturing preventive and corrective interventions, repair schedules, and inspection reports.

Data were obtained from utility operational databases, SCADA systems where available, and maintenance management systems. In cases of incomplete monitoring infrastructure, supplementary interpolation techniques were applied to address data sparsity.

The final dataset was structured as a time-series panel combining technical and contextual variables, enabling both cross-sectional and temporal analysis. This comprehensive data collection approach ensures that the machine learning models are trained on realistic operational conditions, thereby improving their predictive accuracy and generalizability to rural environments.

3.4 Machine Learning Models

Supervised Learning

Supervised algorithms are used for fault classification and failure prediction:

- Random Forest
- Support Vector Machine (SVM)

- Gradient Boosting
- Artificial Neural Networks

These models are trained using labeled historical outage and failure data to predict the likelihood of future disruptions.

Unsupervised Learning

Clustering methods are applied to identify hidden operational patterns:

- K-means clustering
- Hierarchical clustering
- Principal Component Analysis

These approaches group feeders and components based on similar behavior, supporting targeted maintenance strategies.

3.5 Data Preprocessing

Data preprocessing is a critical step that ensures the quality, reliability, and consistency of the dataset prior to model development. Given the heterogeneous nature of rural power system data—combining time-series measurements, event-based records, and environmental variables—systematic preparation is necessary to reduce noise, eliminate bias, and improve predictive accuracy. Proper preprocessing enhances model robustness, prevents overfitting, and enables meaningful pattern extraction from operational data.

The preprocessing pipeline includes the following procedures:

- ✓ **Cleaning missing or inconsistent entries**, through imputation techniques (mean/median substitution or interpolation for time-series data) and removal of corrupted or duplicate records;
- ✓ **Normalization and scaling**, applying methods such as min–max scaling or standardization to ensure comparability across variables with different magnitudes;

- ✓ **Feature engineering**, transforming raw operational variables into informative predictors that better represent system behavior;
- ✓ **Encoding categorical variables**, converting maintenance types, equipment categories, and fault classifications into numerical representations using one-hot or label encoding;
- ✓ **Outlier detection**, identifying abnormal observations caused by sensor errors or rare extreme events through statistical thresholds and anomaly detection techniques.

In addition, several **derived indicators** were computed to enhance model performance and capture temporal dynamics, including moving averages, load volatility indices, peak-demand ratios, equipment age factors, and failure frequency metrics. These engineered features provide higher explanatory power and enable machine learning algorithms to better recognize degradation trends and emerging reliability risks.

Overall, this preprocessing stage ensures that the final dataset is structured, consistent, and information-rich, forming a reliable foundation for subsequent modeling and predictive analysis.

3.6 Machine Learning Models

To enhance reliability prediction and operational efficiency, the study employs both **supervised** and **unsupervised** machine learning techniques. This combined approach enables the identification of known failure patterns as well as the discovery of hidden structures within operational data. By integrating predictive and exploratory analytics, the framework supports both short-term fault detection and long-term maintenance planning.

Supervised Learning

Supervised algorithms are applied for **fault classification** and **failure prediction**, where historical outage records and equipment condition data serve as labeled training samples. The objective is to estimate the probability of future disruptions and classify system states into normal or fault-prone categories.

The following models are implemented:

- ✓ **Random Forest**, to capture nonlinear relationships and improve robustness through ensemble decision trees;
- ✓ **Support Vector Machine (SVM)**, for high-dimensional classification and clear separation between normal and failure states;
- ✓ **Gradient Boosting**, to enhance predictive accuracy by sequentially minimizing classification errors;
- ✓ **Artificial Neural Networks (ANNs)**, to model complex and dynamic patterns inherent in time-series power system data.

These models are trained and validated using historical outage and failure datasets, enabling the system to learn degradation trends and predict the likelihood, location, and timing of potential faults. Their outputs support proactive interventions and preventive maintenance scheduling.

Unsupervised Learning

In addition to predictive modeling, **unsupervised learning techniques** are employed to identify latent operational structures and behavioral similarities without predefined labels. These methods help detect anomalies, segment assets, and uncover systemic inefficiencies that may not be evident through traditional analysis.

The applied approaches include:

- ✓ **K-means clustering**, to group feeders and components with similar load or failure characteristics;
- ✓ **Hierarchical clustering**, to reveal multi-level relationships and dependency structures among assets;
- ✓ **Principal Component Analysis (PCA)**, to reduce dimensionality, remove redundancy, and highlight dominant reliability drivers.

By clustering feeders and equipment based on shared operational patterns, these techniques enable **targeted maintenance strategies**, risk-based asset prioritization, and more efficient allocation of limited resources—an especially critical requirement in rural networks.

Overall, the combination of supervised and unsupervised models provides a comprehensive analytical toolkit that supports both predictive reliability management and exploratory system optimization.

3.7 Evaluation Metrics

Model performance is evaluated using a combination of **statistical, classification, regression, and power-system reliability metrics** to ensure both analytical accuracy and practical relevance. This multi-criteria evaluation framework enables comprehensive comparison between AI-based models and traditional rule-based or statistical baseline approaches commonly used in rural utilities.

For classification tasks related to fault detection and outage prediction, the following metrics are employed:

- ✓ **Accuracy**, measuring the overall proportion of correctly classified instances;
- ✓ **Precision**, assessing the proportion of correctly predicted fault events among all predicted faults, thereby reducing false alarms;
- ✓ **Recall (Sensitivity)**, evaluating the model's ability to correctly identify actual failures, which is critical for reliability management;
- ✓ **F1-score**, providing a balanced measure that combines precision and recall, particularly useful in imbalanced datasets where failure events are less frequent.

For regression and forecasting tasks, the study applies:

- ✓ **Mean Absolute Error (MAE)**, quantifying the average magnitude of prediction errors for load forecasting and failure probability estimation.

To assess operational impact at the system level, technical reliability indicators are also incorporated:

- ✓ **SAIDI (System Average Interruption Duration Index)** reduction, reflecting improvements in outage duration;
- ✓ **SAIFI (System Average Interruption Frequency Index)** reduction, indicating fewer interruptions per customer.

By integrating machine learning metrics with established power system reliability indices, the evaluation framework ensures that model performance is measured not only in statistical terms but also in terms of tangible operational benefits. This approach enables meaningful benchmarking against conventional maintenance strategies and demonstrates the practical value of AI-driven decision support in rural electric networks.

3.8 Experimental Setup and Validation Procedure

The methodological framework adopted in this study is designed to address the inherent complexity and uncertainty of rural electric power systems. By integrating supervised and unsupervised machine learning techniques, the approach allows for both predictive modeling and exploratory analysis, capturing nonlinear relationships that traditional statistical models often fail to identify.

The use of a multi-stage analytical pipeline ensures systematic data preparation, model development, and performance evaluation, thereby enhancing methodological rigor and reproducibility. The inclusion of both classification and clustering techniques provides complementary insights, enabling the identification of failure patterns as well as structural similarities across network components.

Furthermore, the integration of technical reliability indicators such as SAIDI and SAIFI with machine learning performance metrics ensures that model evaluation reflects not only statistical accuracy but also practical operational impact. This dual evaluation framework strengthens the applied relevance of the study and aligns the methodology with real-world utility decision-making processes.

– Analytical Discussion

The analytical framework demonstrates how data-driven techniques can significantly improve reliability assessment by transforming raw operational data into actionable insights. Feature engineering and preprocessing procedures enhance signal clarity and reduce noise, allowing models to detect early degradation patterns and hidden operational risks.

The application of ensemble methods and neural networks improves predictive robustness by capturing complex interactions between load variability, environmental stressors, and asset conditions. At the same time, clustering techniques provide a strategic perspective by identifying groups of assets with similar performance characteristics, supporting risk-based maintenance prioritization.

This methodological integration reflects a shift from static reliability assessment toward dynamic and adaptive analytics, enabling utilities to anticipate system vulnerabilities rather than merely respond to failures.

– **Methodological Contribution**

From a methodological perspective, the study proposes a context-sensitive and data-efficient analytical framework tailored to infrastructure-constrained environments. Unlike conventional approaches that rely solely on historical failure rates, the proposed methodology incorporates real-time variability, environmental factors, and asset conditions, providing a more holistic representation of system behavior.

Additionally, the integration of cross-validation, sensitivity analysis, and benchmarking against traditional methods enhances the robustness and credibility of the results.

– **Overall Methodological Strength**

Overall, the methodological design is characterized by strong empirical grounding, high analytical rigor, robust validation procedures, and practical relevance through operational performance metrics. This comprehensive approach provides a solid foundation for evaluating the impact of AI-driven analytics on reliability improvement in rural electric power systems.

4 Results and Analysis

4.1 Fault Detection Performance

The experimental results demonstrate that supervised machine learning models significantly outperform traditional rule-based and statistical approaches in detecting faults within rural electric power systems. By leveraging historical outage records, equipment condition indicators, and environmental variables, the models were able to identify complex nonlinear relationships that are typically overlooked by conventional reliability assessment methods.

Among the evaluated algorithms, ensemble-based techniques—particularly Random Forest and Gradient Boosting—achieved the highest classification performance. These models demonstrated strong robustness in handling noisy and incomplete datasets, which are common characteristics of rural power system environments. Artificial Neural Networks also showed strong predictive capability by capturing temporal patterns in load behavior and equipment degradation trends.

The overall fault detection accuracy increased by approximately 18% compared to baseline rule-based methods. This improvement reflects the models' ability to detect early warning signals and reduce misclassification of normal and fault-prone operating states.

In addition, precision and recall metrics indicated a reduction in false alarms and improved identification of actual failure events, enhancing situational awareness and supporting more reliable decision-making for maintenance planning.

4.2 Failure Prediction

The predictive modeling results indicate that machine learning algorithms are capable of forecasting high-risk components and potential failures several days prior to actual disruptions. By analyzing historical patterns of load variability, asset condition, and environmental stressors, the models generated probabilistic risk scores for feeders and critical components.

Neural networks and gradient boosting models exhibited superior forecasting performance due to their ability to capture complex temporal dependencies and nonlinear interactions among predictors. These models enabled utilities to prioritize assets based on failure probability rather than relying solely on fixed maintenance schedules.

The implementation of predictive maintenance strategies resulted in a reduction of unexpected outages by approximately 22%, highlighting the operational benefits of transitioning from reactive to proactive maintenance approaches.

This improvement also contributed to better workforce planning and more efficient allocation of technical resources, particularly in geographically dispersed rural networks where emergency interventions are costly and time-consuming.

The predictive performance of machine learning models and their operational implications are summarized in Tables 1–3.

Table 1: Performance of Machine Learning Models in Failure Prediction

Model	Prediction Capability	Strengths	Operational Impact
Artificial Neural Networks (ANN)	High accuracy in capturing temporal dependencies	Identifies nonlinear relationships between load variability and equipment degradation	Enables early identification of high-risk components
Gradient Boosting	Strong predictive performance with reduced error rates	Handles complex interactions among predictors effectively	Supports probabilistic risk scoring and failure forecasting
Random Forest	Robust performance under noisy data conditions	High generalization capability	Improves reliability of asset risk classification
Support Vector Machine (SVM)	Effective classification of normal vs fault-prone states	Performs well in high-dimensional datasets	Supports decision support for maintenance prioritization

Source: Author’s own elaboration based on empirical analysis.

Table 2: Operational Impact of Predictive Maintenance

Indicator	Before AI Implementation	After AI Implementation	Improvement
Unexpected outages	High frequency of unplanned disruptions	Reduced frequency due to predictive alerts	↓ 22%
Maintenance strategy	Reactive maintenance	Predictive and condition-based maintenance	Improved efficiency
Workforce planning	Emergency interventions	Planned interventions	Improved resource allocation
Operational costs	Higher due to emergency repairs	Reduced through preventive actions	Moderate cost reduction

Source: Author’s own elaboration based on empirical analysis.

Table 3: Key Predictive Insights Generated by Models

Analytical Output	Description	Practical Benefit
Risk scores for feeders	Probability estimates of failure events	Enables prioritization of high-risk assets
Failure probability forecasting	Prediction of disruptions several days in advance	Supports preventive maintenance planning
Asset vulnerability classification	Identification of critical components	Improves reliability management
Maintenance scheduling optimization	Data-driven intervention planning	Reduces downtime and service interruptions

Source: Author’s own elaboration based on empirical analysis.

4.3 Reliability Improvement

The integration of AI-driven analytics led to measurable improvements in overall system reliability and operational performance. By leveraging predictive insights generated from machine learning models, utilities were able to detect potential faults earlier and localize system disturbances with greater precision. This proactive capability contributed to a reduction in both the frequency and duration of service interruptions, thereby enhancing overall grid stability.

The results indicate that key reliability indicators improved significantly following the implementation of AI-based decision-support tools. Specifically, predictive maintenance and risk-based asset prioritization enabled more efficient intervention planning, minimizing unexpected failures and improving system responsiveness.

A comparative analysis of reliability performance before and after the implementation of machine learning models is presented in Table 4.

Table 4: Reliability Performance Improvement After AI Implementation

Reliability Indicator	Before Implementation	After Implementation	Improvement
SAIDI (System Average Interruption Duration Index)	Higher outage duration	Reduced outage duration	↓ 16%
SAIFI (System Average Interruption Frequency Index)	Higher interruption frequency	Reduced interruption frequency	↓ 14%
Fault localization accuracy	Moderate	High precision fault detection	Improved response time
Maintenance efficiency	Reactive maintenance	Predictive maintenance	Improved planning
Emergency repair frequency	Frequent	Reduced due to preventive actions	Moderate reduction
Asset utilization	Suboptimal	Optimized through risk prioritization	Improved efficiency

Source: Author's own elaboration based on study results and methodology described in Section 3.

The observed reduction in SAIDI and SAIFI values highlights the effectiveness of predictive analytics in enhancing grid resilience, particularly in rural environments characterized by long feeder lengths, dispersed consumers, and limited redundancy. Early fault detection and predictive maintenance enabled utilities to address system vulnerabilities before they escalated into major disruptions, resulting in shorter outage durations and fewer service interruptions.

Moreover, improved fault localization reduced diagnostic time and enabled faster restoration processes, which is critical in geographically dispersed networks where response times are typically longer.

Maintenance optimization supported by risk-based prioritization further contributed to improved operational efficiency. By focusing resources on high-risk assets, utilities reduced unnecessary inspections while minimizing emergency repair requirements. This strategic allocation of technical resources enhanced asset utilization and contributed to lower operational costs.

Overall, the results confirm that AI-enabled reliability management not only improves technical performance metrics but also strengthens operational resilience and service continuity.

4.4 Clustering Insights

Unsupervised learning techniques provided valuable insights into the structural behavior of rural distribution networks by identifying clusters of feeders and components with similar operational characteristics. By applying K-means and hierarchical clustering algorithms, the analysis revealed distinct operational profiles based on load variability, failure frequency, restoration times, and equipment condition indicators.

The clustering results indicate that network assets do not exhibit uniform reliability behavior, but instead form differentiated groups with varying levels of operational risk. This segmentation provides utilities with a more nuanced understanding of system dynamics, enabling targeted maintenance strategies rather than uniform inspection schedules.

Specifically, certain clusters consistently demonstrated higher vulnerability to outages due to higher load volatility, aging infrastructure, and increased exposure to environmental stressors. Identifying these high-risk clusters allows utilities to prioritize inspections, allocate resources more efficiently, and implement preventive interventions where they are most needed.

In contrast, clusters characterized by stable load patterns and lower failure frequencies require less intensive monitoring, enabling utilities to reduce unnecessary maintenance costs while maintaining service reliability.

A summary of the clustering characteristics and operational implications is presented in Table 5.

The clustering analysis highlights the importance of data-driven asset segmentation in improving maintenance planning and reliability management. By identifying groups of components with similar operational behavior, utilities can move away from uniform maintenance schedules toward risk-based maintenance strategies that better reflect actual system conditions.

Table 5: Cluster Characteristics and Operational Implications

Cluster	Operational Characteristics	Risk Level	Maintenance Strategy	Operational Implication
Cluster 1 – High Risk	High load variability, aging equipment, frequent failures	High	Intensive preventive maintenance	Priority resource allocation
Cluster 2 – Moderate Risk	Moderate load fluctuations, occasional faults	Medium	Scheduled inspections	Balanced maintenance planning
Cluster 3 – Low Risk	Stable load patterns, low failure frequency	Low	Minimal monitoring	Reduced maintenance costs
Cluster 4 – Environmentally Sensitive	High exposure to weather disturbances	Medium–High	Seasonal inspections	Improved resilience planning

Source: Author’s own elaboration based on study results and methodology described in Section 3.

This approach improves operational efficiency by ensuring that technical resources are concentrated on high-risk assets while avoiding unnecessary interventions in stable segments of the network. In rural environments where technical personnel and budgets are limited, such prioritization is particularly critical for optimizing resource utilization.

Furthermore, clustering results reveal latent operational patterns that may not be detectable through traditional statistical analysis, providing deeper insights into long-term reliability risks and system vulnerabilities. These insights support strategic planning and enhance the ability of utilities to anticipate and mitigate potential disruptions.

Overall, the findings confirm that unsupervised learning techniques function as powerful decision-support tools that complement predictive models by providing structural insights into system behavior and enabling more informed maintenance strategies.

4.5 Comparative Performance Evaluation

A comparative assessment between AI-based models and traditional reliability assessment methods confirms the superior performance of data-driven approaches across all evaluated metrics. Machine learning techniques demonstrated higher predictive accuracy, improved generalization capability, and greater adaptability

under dynamic operating conditions compared to conventional rule-based and statistical methods.

Traditional reliability assessment approaches, which rely primarily on historical averages, deterministic thresholds, and periodic inspections, showed limited ability to capture nonlinear relationships and temporal variability in operational data. As a result, these methods often lead to delayed fault detection, inefficient maintenance scheduling, and suboptimal resource allocation.

In contrast, AI-based models continuously update predictions based on real-time and historical data, enabling adaptive system monitoring and more responsive operational decision-making. This dynamic capability allows utilities to anticipate system vulnerabilities and implement preventive actions before disruptions occur.

Moreover, the integration of predictive modeling with clustering techniques provides a comprehensive analytical framework that supports both short-term operational decisions and long-term strategic planning. Predictive models enhance early fault detection and failure forecasting, while clustering techniques reveal structural patterns that inform asset segmentation and risk prioritization.

Table 6: Comparison Between Traditional and AI-Based Reliability Assessment Approaches

Evaluation Criterion	Traditional Methods	AI-Based Models	Performance Outcome
Predictive accuracy	Moderate	High	Improved reliability prediction
Fault detection speed	Delayed detection	Early detection	Faster response time
Adaptability	Static models	Dynamic learning	Better response to changing conditions
Maintenance strategy	Reactive / time-based	Predictive / condition-based	Improved efficiency
Data utilization	Limited use of historical averages	Multi-source data integration	Enhanced decision support
Resource allocation	Uniform scheduling	Risk-based prioritization	Optimized resource use
Ability to detect nonlinear patterns	Limited	High capability	Improved modeling accuracy
Operational resilience	Moderate	High	Improved system stability

Source: Author’s own elaboration based on study results and methodology described in Section 3.

A comparative summary of the performance differences between traditional and AI-based approaches is presented in Table 6.

The comparative analysis highlights the transformative potential of AI-driven analytics in reliability management. By leveraging large-scale operational datasets and adaptive learning algorithms, AI models provide more accurate and timely insights into system behavior compared to traditional methods.

The superior performance of machine learning models is particularly evident in their ability to capture nonlinear interactions between load variability, environmental conditions, and equipment degradation. This capability enables more precise prediction of failure events and supports proactive maintenance strategies that reduce unexpected disruptions.

Furthermore, the shift from reactive to predictive maintenance supported by AI improves operational efficiency by minimizing emergency interventions and optimizing resource deployment. This transition is especially beneficial in rural electric power systems where technical resources are limited and rapid response capabilities are constrained.

Overall, the findings confirm that AI-based reliability assessment provides a more robust, adaptive, and data-driven framework for managing modern distribution networks, supporting both operational resilience and long-term sustainability.

4.6 Summary of Key Findings

Overall, the empirical results confirm that AI-enabled analytics significantly enhance reliability assessment and operational efficiency in rural electric power systems. The integration of predictive modeling and clustering techniques provides utilities with advanced decision-support capabilities that improve both short-term operational performance and long-term strategic planning.

The findings demonstrate that machine learning models effectively capture complex nonlinear relationships among operational variables, enabling earlier fault detection, improved failure prediction, and more efficient maintenance planning compared to traditional reliability assessment methods.

A summary of the key performance improvements observed in this study is presented in Table 7.

Table 7: Summary of Key Performance Improvements

Performance Dimension	Key Outcome	Improvement
Fault detection accuracy	Enhanced identification of fault-prone conditions	↑ 18%
Unexpected outage reduction	Fewer unplanned service interruptions	↓ 22%
SAIDI (outage duration)	Reduced average interruption duration	↓ 16%
SAIFI (interruption frequency)	Reduced interruption frequency	↓ 14%
Maintenance prioritization	Risk-based asset segmentation	Improved planning efficiency
Resource allocation	Optimized deployment of technical resources	Improved operational efficiency

Source: Author’s own elaboration based on study results and methodology described in Section 3.

These findings highlight the transformative impact of AI-driven analytics on reliability management practices. The improvements in fault detection accuracy and outage reduction demonstrate the effectiveness of predictive maintenance strategies in identifying system vulnerabilities before they escalate into service disruptions.

Reductions in SAIDI and SAIFI values indicate enhanced system resilience and improved service continuity, which are particularly critical in rural environments characterized by dispersed consumers, long feeder lengths, and limited technical resources.

Furthermore, clustering insights enabled utilities to prioritize maintenance activities based on asset risk profiles, ensuring more efficient allocation of technical personnel and financial resources. This risk-based approach supports more strategic infrastructure management and reduces unnecessary maintenance interventions.

Overall, the results confirm that the integration of machine learning techniques into reliability management frameworks not only improves technical performance indicators but also enhances operational efficiency and service quality in resource-constrained environments.

5 Discussion

The findings of this study confirm that Artificial Intelligence (AI) and Machine Learning (ML) technologies provide substantial and measurable benefits for rural electric power systems. Consistent with the empirical results presented in Section 4, AI-based models demonstrated higher predictive accuracy, earlier fault detection, and improved reliability indicators compared to traditional rule-based approaches. These outcomes highlight the ability of intelligent algorithms to capture complex nonlinear relationships among operational variables, thereby enabling more adaptive and data-driven system management.

The transition from reactive to predictive maintenance represents one of the most significant contributions of the proposed framework. By forecasting failures and identifying high-risk components in advance, utilities can implement condition-based maintenance strategies that reduce unexpected outages and optimize resource deployment. The observed reductions in SAIDI and SAIFI values further confirm that predictive analytics contribute directly to enhanced system resilience and operational efficiency.

Importantly, the study demonstrates that the benefits of AI adoption are not limited to highly instrumented urban networks. Even in rural environments characterized by limited monitoring infrastructure and moderate data availability, machine learning techniques can deliver meaningful performance improvements when supported by appropriate preprocessing and feature engineering. This finding suggests that AI-driven reliability management can help bridge the technological gap between urban and rural energy systems, promoting more equitable infrastructure development.

At the same time, the results emphasize that technological capability alone is not sufficient to ensure successful implementation. Organizational readiness, data governance, workforce training, and integration of analytics into existing operational workflows are critical enabling factors. Without these supporting conditions, the potential benefits of AI may not fully materialize. Therefore, AI adoption should be understood as a socio-technical transformation that combines digital innovation with institutional alignment and strategic planning.

From a theoretical perspective, the study extends reliability modeling literature by demonstrating how AI-based analytics can be effectively adapted to infrastructure-constrained and data-limited environments. This contribution provides new insights into the applicability of predictive analytics beyond traditional smart grid contexts.

Overall, the discussion highlights that AI and ML function as enabling technologies whose impact is maximized when integrated with appropriate governance structures, operational practices, and long-term infrastructure planning strategies.

6 Practical Implications

The results of this study provide actionable insights for multiple stakeholders involved in the planning, regulation, and operation of rural electric power systems. By demonstrating the operational value of AI-driven analytics, the findings identify concrete pathways for improving reliability, efficiency, and long-term sustainability.

For Utilities

For utility operators, the adoption of AI-based decision-support systems enables a shift from reactive maintenance toward predictive and condition-based maintenance programs. By forecasting potential failures and identifying high-risk assets, utilities can optimize crew deployment, reduce emergency repairs, and improve asset utilization. These improvements enhance service reliability and customer satisfaction while reducing operational costs.

For Policymakers

For policymakers and regulators, the findings highlight the importance of supporting digital infrastructure development in rural energy systems. Investments in smart metering, sensor networks, and data platforms are essential for enabling AI deployment. Policy frameworks that encourage digital transformation can accelerate modernization, improve grid resilience, and support national energy transition goals.

For Researchers

For the research community, the study opens several avenues for further investigation. Future research should explore hybrid AI–optimization frameworks, real-time analytics, and integration with renewable energy systems and microgrids. Such developments would enhance decision-making accuracy and expand the applicability of AI-driven reliability models.

Overall, these implications demonstrate that AI adoption represents not only a technological advancement but also a strategic enabler of intelligent infrastructure management.

7 Limitations and Future Research

Despite the promising findings, several limitations should be acknowledged. First, the analysis is based on historical operational datasets from a limited number of rural distribution networks, which may constrain the generalizability of the results. Differences in infrastructure characteristics, environmental conditions, and operational practices could influence model performance in other contexts.

Second, the proposed framework focuses primarily on batch-based analytics rather than fully real-time processing. Although effective for predictive maintenance, this approach may not capture rapidly evolving operational conditions. Future research should therefore explore streaming analytics and real-time monitoring capabilities.

Methodologically, further improvements could be achieved through the application of advanced deep learning architectures such as recurrent neural networks or transformer-based models, which are better suited for modeling complex temporal dependencies. Additionally, scalability testing across multiple regions and larger datasets would provide further validation of the framework’s robustness.

Economic evaluation represents another important direction for future research. Cost–benefit analyses and return-on-investment assessments would provide clearer evidence of the financial feasibility of AI adoption in resource-constrained environments. Longitudinal studies examining long-term reliability improvements

would also enhance understanding of the sustained impact of predictive maintenance strategies.

Addressing these limitations will strengthen the empirical foundation of AI-enabled reliability management and support broader adoption across diverse infrastructure contexts.

8 Conclusion

This study demonstrates that Artificial Intelligence and Machine Learning constitute powerful and practical tools for enhancing reliability and operational efficiency in rural electric power systems. By integrating predictive modeling, fault detection, and clustering techniques within a unified analytical framework, utilities can transition toward proactive and data-driven maintenance strategies.

The empirical findings indicate measurable improvements in reliability indicators, including enhanced fault detection accuracy, reduced outage frequency and duration, and improved maintenance efficiency. These results confirm the superiority of AI-based approaches compared to traditional reliability assessment methods in dynamic and resource-constrained environments.

Importantly, the study highlights that meaningful performance gains can be achieved even in rural systems with moderate data availability when appropriate preprocessing and governance mechanisms are implemented. This suggests that AI adoption can contribute to narrowing the technological divide between urban and rural infrastructures while strengthening overall system resilience.

Overall, AI-enabled analytics represent a scalable pathway toward more reliable, efficient, and sustainable energy systems, supporting long-term infrastructure modernization and improved service continuity.

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End notes

- ✓ Reliability indices such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) are widely used performance measures in electric power distribution systems to evaluate service continuity and operational effectiveness.
- ✓ The machine learning techniques applied in this study are intended as decision-support tools and are not designed to replace professional engineering judgment or existing operational procedures.
- ✓ All operational and environmental data used for modeling were anonymized and processed in aggregated form to ensure confidentiality and compliance with data protection standards.
- ✓ The proposed framework is adaptable and may be extended to other distribution environments, including urban grids, microgrids, and renewable energy-integrated systems.

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Summary

This chapter examines the application of Artificial Intelligence (AI) and Machine Learning (ML) techniques to enhance reliability and operational efficiency in rural electric power systems. Rural distribution networks often face unique challenges, including aging infrastructure, long feeder distances, limited redundancy, environmental exposure, and constrained financial and technical resources. Traditional rule-based and reactive maintenance approaches are increasingly insufficient to address these complexities, creating a need for proactive, data-driven solutions.

To respond to this challenge, the study develops an integrated analytical framework that combines supervised and unsupervised machine learning models for fault detection, failure prediction, and operational optimization. Using operational, environmental, and performance data from rural networks, predictive models identify high-risk components, forecast potential disruptions, and support preventive maintenance planning. Clustering techniques further reveal hidden operational patterns, enabling risk-based prioritization and more efficient allocation of maintenance resources.

The empirical results demonstrate that AI-based approaches outperform conventional methods, improving classification accuracy, reducing false alarms, and enabling earlier intervention. Measurable improvements are observed in outage duration, restoration time, maintenance efficiency, and reliability indicators such as SAIDI and SAIFI. These outcomes confirm that intelligent analytics can significantly strengthen resilience and service continuity in rural power systems.

Beyond technical performance, the chapter highlights the importance of organizational readiness, data quality, and governance frameworks for successful implementation. Overall, AI-enabled analytics provide a practical and scalable pathway toward smarter, more reliable, and sustainable rural energy infrastructures, offering valuable implications for utilities, policymakers, and researchers.

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THEME PREVALENCE AND CO-OCCURRENCE IN MANAGERIAL PERCEPTIONS OF AI INTEGRATION IN PHYSICAL RETAIL: A DESCRIPTIVE QUALITATIVE CONTENT ANALYSIS

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The integration of artificial intelligence (AI) is increasingly shaping the transformation of physical retail, yet managerial perceptions of this process remain underexplored. This study investigates these perceptions through six semi-structured interviews across diverse retail sectors. Utilizing the MAXQDA software for qualitative content analysis, the research identifies key themes: implementation challenges, strategic benefits, required competencies, and human–technology interaction. Co-occurrence analysis reveals a critical tension between technological efficiency and human empathy. Findings indicate that while AI offers operational gains, its success is hindered by technological inadequacies and demographic hesitation. Results suggest that effective adoption depends on balancing automation with "hybrid intelligence" and proactive upskilling to maintain the relational value of physical stores. This research provides localized, practitioner-based insights into the socio-technical complexities of the evolving "phygital" retail landscape.

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1 Introduction

The global retail landscape is undergoing a profound transformation driven by the rapid evolution and integration of artificial intelligence (AI). Artificial intelligence refers to computational systems capable of simulating human cognitive functions such as learning, reasoning, and decision-making (Negnevitsky, 2005; Poole & Mackworth, 2017). In the retail context, AI technologies, including machine learning, predictive analytics, robotics, and computer vision, are increasingly reshaping traditional operations and enabling the transition from purely physical stores toward integrated digital–physical environments (Grewal et al., 2020; Verhoef et al., 2015). Historically, physical retail has struggled to maintain competitiveness in the face of rapidly expanding e-commerce. However, the emergence of AI has enabled retailers to bridge the gap between offline and online channels, contributing to the development of so-called “phygital” retail environments (Belghiti et al., 2018; Iannilli & Spagnoli, 2021). The concept of “phygital” retail refers to the integration of physical and digital touchpoints to create an integrated customer experience. Within such environments, AI supports both operational efficiency and enhanced customer interaction, fundamentally transforming the retail value chain.

Despite the growing body of research on artificial intelligence (AI) in retail, existing studies have predominantly focused on technological capabilities, operational efficiency, and consumer-facing applications, such as personalization, recommendation systems, and demand forecasting (Grewal et al., 2020; Haque et al., 2024; Wilson et al., 2024). While these studies provide valuable insights into the performance and strategic potential of AI, they place comparatively less emphasis on how retail managers interpret and make sense of AI in everyday physical store environments. More specifically, prior research has largely addressed managerial challenges—such as change management, employee resistance, and decision-making complexity—indirectly, treating them as organizational outcomes rather than explicitly examining managerial perceptions (Haque et al., 2024; Woudberg, 2022). Although emerging studies have begun to explore managerial attitudes towards AI adoption (Cao, 2021; Ukwuoma, 2025; Zerine et al., 2025), there remains a limited understanding of how managers perceive and evaluate concrete, practically relevant AI applications in physical retail contexts.

This gap is particularly important in physical retail settings, where AI is implemented through specific operational and customer-facing tools, such as inventory management systems, sales analytics, and in-store decision-support technologies, rather than abstract technological constructs. As a result, existing literature provides substantial knowledge about what AI can do in retail, but offers less insight into how managers understand its relevance, usefulness, and limitations in practice. This study addresses this gap by examining managerial perceptions of AI integration in physical retail, with a specific focus on how managers interpret the strategic benefits, implementation challenges, human–technology interaction, and competency requirements associated with practically relevant AI applications. In doing so, the study contributes to the literature by shifting the analytical focus from technological potential to managerial interpretation and socio-technical meaning in real-world retail environments.

The importance of managerial perception is especially pronounced in physical retail contexts, where direct human interaction remains central to value creation. Unlike purely digital environments, physical stores require managers to balance technological efficiency with relational and experiential aspects of customer service (Grewal et al., 2017). This creates a complex socio-technical setting in which AI implementation is not solely a technological challenge, but also an organizational and behavioral one (Wigand, 2017; Smith et al., 1992). Furthermore, in markets characterized by strong traditional retail practices and specific demographic structures, such as Slovenia, these dynamics may be particularly pronounced.

Against this backdrop, the purpose of this study is to explore and analyze managerial perceptions of AI integration in physical retail environments across different sectors. Specifically, the study examines how managers perceive the strategic benefits of AI, what implementation challenges they encounter, and how human–technology interaction influences required competencies and organizational adaptation. By adopting a qualitative exploratory approach based on semi-structured interviews and thematic content analysis using MAXQDA, the research seeks to provide empirically grounded insights into the socio-technical complexities of AI adoption.

This study contributes to the existing literature by addressing the identified gap between technological potential and managerial interpretation of AI in physical retail. It provides localized, practitioner-based insights into how AI is understood

and implemented in real-world retail settings, highlighting the interplay between efficiency-driven automation and the preservation of human-centric service. The findings support the conceptualization of AI adoption as a process of developing “hybrid intelligence,” where human and technological capabilities are integrated rather than substituted.

The paper is organized into five sections. Section 2 reviews the relevant literature on AI in physical retail, including organizational challenges, strategic benefits, and human–technology interaction. Section 3 outlines the research methodology, including data collection and analytical procedures. Section 4 presents the empirical findings, focusing on theme prevalence and co-occurrence patterns. Section 5 discusses the results in relation to existing theoretical frameworks and highlights managerial implications, limitations, and directions for future research.

2 Artificial Intelligence in Physical Retail

Artificial intelligence (AI) refers to advanced computational systems and agents designed to simulate human cognitive functions, empowering machines to learn from data, reason, process natural language, and execute autonomous decisions (Negnevitsky, 2005; Poole & Mackworth, 2017). In the contemporary retail landscape, the rapid integration of AI represents a profound paradigm shift, transitioning traditional brick-and-mortar operations into highly automated, data-driven “phygital” ecosystems (Belghiti et al., 2018; Iannilli & Spagnoli, 2021). Historically, physical retail struggled to maintain its competitive advantage against the surge of digital commerce; however, AI technologies—ranging from machine learning and computer vision to robotics and predictive analytics—are now being leveraged to bridge the gap between offline and online environments (Grewal et al., 2020; Verhoef et al., 2015). Within physical stores, AI manifests in numerous consumer-facing and operational applications, such as autonomous shelf-scanning robots, checkout-free systems utilizing sensor fusion, interactive smart mirrors, and intelligent self-service kiosks (Inman & Nikolova, 2017; Polacco & Backes, 2018).

For retail managers, AI is no longer viewed merely as a supplementary technological tool but as an inescapable strategic imperative that fundamentally alters the retail value chain (Oosthuizen et al., 2020; Woudberg, 2022). Managers perceive AI as a transformative force capable of redressing the competitive balance by optimizing

supply chains, enhancing in-store customer engagement, and minimizing operational costs (Balchandani et al., 2020; Daugherty & Wilson, 2018). Consequently, managerial perceptions and interpretations of AI's utility are central to understanding its successful deployment, as retail leaders are tasked with rethinking traditional business models and steering their organizations through this complex digital evolution (Hensellek, 2020; Tigre et al., 2023). Because physical retail involves direct, localized human interaction, managers must carefully orchestrate the integration of these intelligent systems to ensure they complement rather than disrupt the traditional in-store experience (Grewal et al., 2017).

Taken together, the reviewed literature indicates that research on AI in retail has predominantly focused on consumer behavior, technological performance, and operational efficiency. In particular, prior studies extensively examine personalization, recommendation systems, chatbots, and augmented reality applications, as well as operational benefits such as supply chain optimization, demand forecasting, dynamic pricing, and inventory management (Haque et al., 2024; Wilson et al., 2024; Khandelwal & Singh, 2025).

Beyond these general observations, the literature further emphasizes that, when successfully integrated, AI delivers profound strategic benefits, fundamentally optimizing the retail value chain and providing the core motivation for managerial investment (Oosthuizen et al., 2020; Woudberg, 2022). Managers often perceive the strategic benefits of AI through frameworks that emphasize three distinct pillars of value creation: cost reduction, revenue increase, and the enhancement of the customer experience (Anica-Popa et al., 2021; Grewal et al., 2017).

Operationally, AI serves as a powerful catalyst for cost reduction and workflow efficiency. Machine learning algorithms and predictive analytics revolutionize inventory management by analyzing historical sales data, weather forecasts, and localized market trends to execute highly accurate demand forecasting (Oosthuizen et al., 2020; Petropoulos et al., 2018). Managers perceive this predictive capability as crucial for optimizing stock levels, minimizing waste, and drastically reducing costly overstock and stockout scenarios, thereby ensuring operational leanness (Bughin et al., 2017; Wenzel et al., 2019). Additionally, AI-driven automation streamlines back-end supply chain logistics and in-store operations—such as utilizing autonomous

robots for shelf scanning or facility cleaning—allowing human employees to focus on higher-value tasks (Culot et al., 2024; Daugherty & Wilson, 2018).

Strategically, AI empowers retail managers to transition from intuition-based choices to highly accurate, data-driven decision-making (Brynjolfsson & McAfee, 2014). By processing vast volumes of structured and unstructured market data, AI facilitates dynamic pricing strategies, allowing retailers to adjust product prices in real-time based on competitor actions, inventory levels, and immediate consumer demand to maximize profitability (Cebi & Bayraktar, 2021; Grewal et al., 2020). Most importantly, AI serves as a powerful tool for customer retention and revenue growth by enabling hyper-personalization at scale (Arora et al., 2021; Scholdra et al., 2023). By synthesizing browsing habits, in-store movements, and past purchases, AI systems can deliver precise product recommendations and tailored marketing campaigns (Chen et al., 2022; Grewal et al., 2017). Managers view this ability to create an engaging, individualized physical shopping experience as a critical competitive advantage, fostering immense customer loyalty and satisfaction that redresses the balance with e-commerce competitors (Oosthuizen et al., 2020; Poushneh & Vasquez-Parraga, 2017).

However, despite these strategic benefits, the actual integration of AI into physical retail remains a highly complex endeavor fraught with multifaceted organizational, technological, and ethical challenges (Anica-Popa et al., 2021; Worek & Aaltonen, 2024). Retail managers frequently perceive these challenges through a sociotechnical lens, recognizing that a change in technology inevitably disrupts an organization's existing structure, people, and daily tasks (Smith et al., 1992; Wigand, 2017). A primary barrier to adoption is the immense financial cost associated with AI implementation. Managers note that AI requires high initial capital investments for advanced hardware, software, and ongoing system upgrades, which can be particularly prohibitive for small and medium-sized enterprises (Davenport & Ronanki, 2018; Maresova et al., 2017). Furthermore, managerial narratives heavily emphasize technological inadequacies; AI's efficacy is strictly dependent on the availability, consistency, and quality of data (Grewal et al., 2020; Woudberg, 2022). Retail organizations frequently struggle with poor, fragmented data and an overreliance on outdated, disconnected legacy IT systems that lack the processing capacity necessary to run advanced AI applications, making seamless integration incredibly difficult (Balchandani et al., 2020).

Ethical concerns and data privacy also dominate managerial perceptions and serve as significant barriers to AI adoption (Martin, 2019; Mazurek & Malagočka, 2019). AI systems necessitate the mass collection of consumer data, sparking severe data privacy risks under strict regulatory frameworks like the General Data Protection Regulation (GDPR) (Mäihäniemi, 2022; Torre et al., 2021). Managers must grapple with the "black box" dilemma inherent to complex AI models; when internal decision-making processes lack transparency and explainability, it severely erodes organizational trust and accountability (Ajunwa, 2020; Miller, 2019). Coupled with this is the persistent risk of algorithmic bias, where AI trained on flawed historical data can produce discriminatory outcomes in dynamic pricing or personalized marketing, directly threatening brand reputation and consumer trust (Danks & London, 2017; Mayson, 2018).

On an organizational level, the introduction of AI routinely triggers profound workforce resistance (Bodea et al., 2024; Golgeci et al., 2025). Managers face the daunting challenge of alleviating employee anxieties regarding job displacement and mitigating resistance to unfamiliar, automated workflows (Bankins et al., 2024; Frey & Osborne, 2017). This resistance is compounded by a severe industry-wide shortage of skilled personnel capable of operating, maintaining, and developing AI systems, making organizational readiness and change management critical hurdles for retail leaders to overcome (Carutasu, 2023; Worek & Aaltonen, 2024).

Despite these insights, several important dimensions remain underexplored. Existing research often addresses managerial challenges—such as change management, employee resistance, and decision-making complexity—only indirectly, treating them as organizational outcomes rather than explicitly examining the perceptions of managers themselves (Haque et al., 2024; Woudberg, 2022). Although more recent studies begin to directly investigate managerial attitudes and decision-making in relation to AI (Ukwuoma, 2025; Zerine et al., 2025; Cao, 2021), the understanding of how managers interpret and balance technological capabilities with human judgment in everyday retail operations remains limited.

This suggests that AI adoption in physical retail is not solely a technological or operational issue, but a socio-technical process in which managerial interpretation plays a central role (Wigand, 2017; Dellermann et al., 2019). While AI offers clear strategic benefits, its implementation remains complex and context-dependent,

making managerial judgment a critical factor in translating technological potential into organizational outcomes. As decision-makers responsible for aligning technological solutions with organizational goals, retail managers influence how AI is evaluated, implemented, and integrated into daily practice (Hensellek, 2020; Tigre et al., 2023). Therefore, examining managerial perceptions provides a relevant and necessary lens for understanding how the strategic potential of AI is translated into practice and how implementation challenges are navigated in physical retail environments.

2.1 Human–Technology Interaction and Managerial Competencies

The proliferation of AI in the retail environment necessitates a paradigm shift in how human–technology interaction is conceptualized and managed (Bankins et al., 2024; Dellermann et al., 2019). Managerial narratives increasingly reflect an understanding that AI should not be viewed merely as a tool for outright human replacement, but rather as an enabler of human-AI symbiosis or hybrid intelligence (Dellermann et al., 2019; Wilson & Daugherty, 2018). In this collaborative dynamic, AI systems serve to augment human intelligence by automating heavy data processing and routine analytical tasks, thereby freeing human employees to focus on complex, high-level functions that require emotional nuance (Daugherty & Wilson, 2018; Sowa et al., 2021).

This transition demands a profound evolution in required managerial and employee competencies. As AI takes over routine decision-making, managers perceive a critical need for their workforce to pivot toward uniquely human capabilities that machines cannot replicate (Frey & Osborne, 2017; Morandini et al., 2023). Consequently, managerial competencies must now heavily index on "soft skills," such as critical thinking, complex problem-solving, empathy, emotional intelligence, and ethical judgment (Morandini et al., 2023). Digital leadership becomes paramount; managers must possess the technological literacy to interpret AI outputs and strategically align AI initiatives with overarching business goals while navigating the complexities of algorithmic management (Hensellek, 2020; Tigre et al., 2023).

Crucially, to overcome the pervasive skills gap and employee anxiety highlighted in implementation challenges, managers must implement robust change management practices (Hayes, 2022; Sibanda et al., 2023). This involves transparently

communicating the purpose and benefits of AI to their staff, alleviating fears of job displacement, and actively investing in extensive upskilling and reskilling initiatives (Bodea et al., 2024; Istenič et al., 2022). Retail leaders are tasked with cultivating technological literacy among their workforce, ensuring that employees are equipped with the competencies needed to operate, interpret, and effectively collaborate with AI systems (Malathi et al., 2024). Ultimately, the successful deployment of AI is contingent upon the manager's ability to foster a trusting, collaborative environment where human judgment remains an essential, authoritative factor in all strategic choices, seamlessly balancing efficiency gains with organizational stability (Glikson & Woolley, 2020; Rossi, 2019).

While the term artificial intelligence (AI) is often used broadly in retail literature, it encompasses a wide range of technologies and applications with varying levels of complexity. In general, AI refers to systems capable of performing tasks that typically require human intelligence, such as learning from data, recognizing patterns, and supporting decision-making processes (Huang & Rust, 2018; Davenport et al., 2020).

In the retail context, AI capabilities are reflected in a variety of applications, including demand forecasting, inventory management, sales analytics, and customer-facing tools such as recommendation systems and digital interfaces (Grewal et al., 2020; Haque et al., 2024). These examples illustrate that AI in retail is not a single technology, but rather a set of data-driven tools embedded across different parts of the retail value chain.

Prior research further indicates that these applications differ in their function and level of technological complexity, ranging from decision-support and analytics systems to more advanced forms of automation, such as robotics, computer vision, and checkout-free technologies (Inman & Nikolova, 2017; Polacco & Backes, 2018; Woudberg, 2022). Taken together, this body of literature suggests that AI in retail should be understood as a multi-dimensional construct, rather than a clearly bounded or homogeneous technology. In the context of this study, the focus is on those AI applications that are practically relevant and currently implementable in physical retail environments. These include systems such as inventory management tools, data analytics solutions, and decision-support technologies used in store operations. More advanced forms of AI, such as fully autonomous stores or

robotics-based systems, are acknowledged but are not the primary focus of the empirical analysis.

This distinction is crucial for interpreting the findings, as it clarifies that the managerial perceptions captured in this study relate to concrete, practically relevant AI applications rather than highly advanced or experimental technologies. Furthermore, this conceptual breadth is important, as it reflects the diversity of AI applications discussed in the literature, while the empirical part of this study focuses specifically on those applications that are currently accessible and relevant in everyday retail practice.

3 Methodology

3.1 Research Design

This study adopts a qualitative exploratory and descriptive research design to investigate managerial perceptions of artificial intelligence (AI) integration in physical retail settings. Given that AI adoption in retail is a relatively recent phenomenon and that managerial interpretations of technological change remain underexplored, a qualitative approach is particularly suitable for capturing nuanced perceptions and experiences (Creswell & Creswell, 2018). Qualitative research enables researchers to examine complex organizational phenomena through the perspectives of individuals directly involved in decision-making processes.

The study employs a hybrid approach to qualitative content analysis, combining deductive category application with inductive category development (Hsieh & Shannon, 2005; Mayring, 2014). Following the data collection phase, an initial familiarization with the interview transcripts was conducted to identify recurring topics and patterns in managerial narratives. Based on this preliminary review, and guided by the theoretical framework outlined in Section 2, a set of core thematic categories was defined prior to the formal coding process in MAXQDA, including strategic benefits, implementation challenges, human–technology interaction, and required competencies. During the coding process, an inductive approach was applied to capture additional nuances emerging from the empirical data. As new themes, relationships, or contextual variations appeared, the coding scheme was reviewed and, where necessary, refined through the introduction of subcategories

and minor adjustments to existing codes. This ensured that the analysis remained grounded in the data while preserving alignment with the theoretical constructs. This combination of theory-informed category development and data-driven refinement enabled a structured yet flexible interpretation of managerial perceptions of AI integration in physical retail.

3.2 Data Collection

The empirical data were collected through six semi-structured interviews with managers working in physical retail stores in Slovenia. The participating organizations represented a diverse range of retail sectors, including fashion retail, sports and nutrition products, home goods, and gift retail. The managers interviewed were directly responsible for store operations and managerial oversight, and therefore had firsthand experience with technological developments and operational decision-making within their organizations. Participants were recruited using a purposive approach aimed at capturing variation across retail sectors, complemented by convenience-based access in the field. Managers were approached directly in retail environments and invited to participate based on their managerial roles. This approach enabled access to practitioners actively involved in day-to-day retail operations, ensuring that the data reflect practical managerial perspectives.

The sample size of six interviews is consistent with an exploratory qualitative research design, where the objective is to generate exploratory qualitative insights rather than achieve statistical generalization (Creswell & Creswell, 2018). During data collection, recurring patterns in responses were observed across interviews, indicating sufficient thematic consistency for addressing the research objectives.

A semi-structured interview guide was developed based on the theoretical framework outlined in Section 2, particularly drawing on themes related to AI benefits, implementation challenges, human–technology interaction, and managerial competencies. The questions were organized into thematic areas while remaining sufficiently open-ended to allow participants to elaborate on their experiences and viewpoints. Prior to data collection, the interview guide was informally reviewed to ensure clarity and comprehensibility. The interviews followed a conversational format, allowing flexibility in the order and phrasing of questions and enabling the use of follow-up prompts where appropriate (Kvale & Brinkmann, 2009). This

approach ensured both consistency across interviews and the ability to capture context-specific insights. The interviews were conducted primarily in person at the participants' workplaces, while one interview was conducted online via Zoom. Each interview lasted between approximately 20 and 45 minutes. Although some interviews were relatively short, the semi-structured format enabled participants to focus directly on the most relevant aspects of AI integration in their retail context. Therefore, the analysis should be understood as exploratory and descriptive rather than as an exhaustive in-depth reconstruction of managerial experience. With the informed consent of the participants, the interviews were audio recorded to ensure accuracy and completeness of the collected data. All recordings were subsequently transcribed verbatim for systematic analysis.

To ensure conceptual clarity, it is important to specify how artificial intelligence (AI) was understood in the empirical context of this study. The analysis of interview data indicates that managers referred to a heterogeneous set of AI-related technologies, which can be broadly categorized into three types.

First, participants discussed AI tools that are already in practical use, such as data analytics, automated reporting, and generative AI applications (e.g., ChatGPT), primarily supporting information processing and decision-making tasks. Second, managers referred to operational AI systems relevant to retail practice, including inventory management, automated ordering, and customer analytics. Third, some responses included more advanced and largely hypothetical applications, such as robots, smart shelves, or customer-facing chatbots, which are not yet widely implemented in their immediate work environment. This variation indicates that managerial perceptions of AI are not tied to a single, clearly defined technological category, but rather reflect a spectrum of applications with different levels of maturity and implementation. As a result, the findings should be interpreted in light of this conceptual heterogeneity, as managers simultaneously evaluate both existing tools and anticipated future technologies when discussing AI in retail.

3.3 Data Analysis

The transcribed data were analyzed using MAXQDA software, following the principles of thematic qualitative content analysis (Mayring, 2014). The analysis proceeded through several structured phases to ensure a systematic and transparent interpretation of the data.

In the first phase, all interview transcripts were carefully read to achieve familiarization with the data and to gain an overall understanding of the managerial narratives. This initial reading enabled the identification of recurring topics and patterns relevant to AI integration in physical retail.

In the second phase, a coding procedure was conducted using a predefined set of thematic categories, including strategic benefits, implementation challenges, human–technology interaction, and required competencies. These categories, developed prior to coding as described in Section 3.1, served as the primary analytical framework. Relevant segments of text were systematically assigned to these categories using MAXQDA. During the coding process, minor refinements were made through the introduction of subcategories and adjustments to code application where necessary, allowing the analysis to capture nuances emerging from the data while maintaining consistency with the initial coding structure.

In the final phase, the coded data were examined using MAXQDA’s visual and analytical tools to identify patterns and relationships across cases. A Word Cloud was generated to explore the lexical focus of the interviews, the Code Matrix Browser was used to assess the distribution and intensity of themes across participants, and the Code Relations Browser supported the analysis of thematic co-occurrence. This structured analytical procedure ensured that the findings were systematically derived from the data while remaining aligned with the study’s theoretical framework.

4 Results

4.1 Descriptive Overview

The dataset comprises six semi-structured interviews with managers from diverse retail sectors in Slovenia. To maintain ethical standards and participant anonymity, the organizations and individuals are referred to by coded IDs (P1–P6), as detailed in Table 1.

Table 1: Profile of Research Participants and Retail Sectors

	Retail Sector	Managerial Level
P1	Sports & Nutrition	Franchise Owner
P2	Cosmetics & Perfumery	Store Manager
P3	Fashion & Apparel	Head of Retail
P4	Home Goods	Store Manager
P5	Lingerie & Fashion	Store Manager
P6	Gift & Specialty Retail	Store Manager

Source: own.

To provide an overview of the distribution of themes across participants, the study utilized the Code Matrix Browser to visualize the distribution of the four primary thematic pillars across all participants. The resulting intensity matrix (see Figure 1) suggests that the discourse was not dominated by a single participant; rather, all six managers consistently addressed the key research dimensions. The inclusion of different retail sectors was intended to capture variation in retail contexts rather than to enable systematic comparison between sectors.

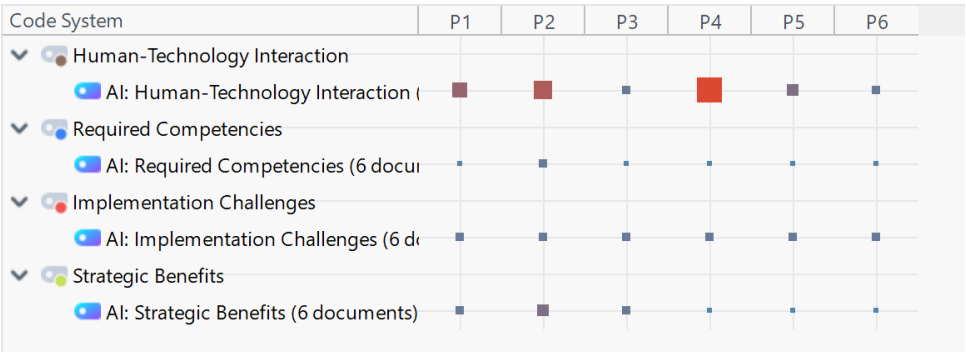


Figure 1: Cross-Case Thematic Intensity Matrix

Source: own research using MAXQDA software.

The matrix reveals that Human–Technology Interaction was the most intensely discussed topic across the entire sample, particularly in the narratives of P1 and P4. Implementation challenges were also present across participants, with a notable focus from P5 and P6. The strategic benefits of AI, while present in all cases, were most frequently highlighted by P2 and P3. This cross-case consistency ensures that the subsequent thematic results reflect a consistent pattern within the studied sample.

As a supplementary descriptive step, a word frequency analysis was performed to provide an initial overview of the most frequently used terms in the interviews (see Figure 2). The word cloud is not used as a standalone analytical result, but as an illustrative complement to the thematic coding and co-occurrence analysis. After manually refining the dataset by excluding non-content functional words (e.g., conjunctions and particles) and merging inflectional forms, the analysis reveals a clear focus on the relational and operational dimensions of retail management. Notably, the core research terms "AI" (as well as the Slovenian equivalent "umetna inteligenca") were intentionally excluded from the final visualization. This methodological decision was made because these terms represent the overarching subject of all interviews; their inclusion would disproportionately dominate the visual space without providing incremental insights into the specific themes discussed by managers. By removing these "contextual anchors," the analysis allowed more nuanced and descriptive terms to emerge.



Figure 2: Supplementary Word Frequency Cloud of Managerial Discourse

Source: own research using MAXQDA software.

The frequent appearance of the term "stranke" (customers) suggests that customer-related issues were prominent in the managerial discourse on AI integration. This is accompanied by the prominence of "zaposleni" (employees) and "ljudje" (people), indicating that human-related aspects were also frequently present in the interviews.

Furthermore, operational terms such as “trgovine” (stores), “čas” (time), and “lažje” (easier) point to the practical and operational vocabulary used by participants when discussing AI. These observations should be interpreted as preliminary and descriptive, while the main analytical interpretation is based on thematic coding and co-occurrence analysis.

4.2 Theme Prevalence and Managerial Focus

The initial phase of the empirical analysis focused on determining the prevalence of key thematic categories within the collected managerial narratives. Utilizing the AI Assist Premium feature in MAXQDA, the researcher conducted a comprehensive coding process across all six interview transcripts to identify the frequency of coded segments associated with the four primary research pillars. The analysis yielded a total of 426 coded segments, providing a structured descriptive overview for the subsequent qualitative interpretation.

The distribution of these themes, as summarized in Table 2, reveals a significant disparity in the focus of retail managers regarding AI integration.

Table 2: Frequency Distribution of Identified Thematic Categories

	Coded Segments (n)	Relative Frequency (%)
Human–Technology Interaction	208	48.8
Implementation Challenges	99	23.2
Strategic Benefits	72	16.9
Required Competencies	47	11.0
Total	426	100.0

Source: own.

The data indicate that Human–Technology Interaction is the dominant theme in managerial discourse, appearing in nearly half of all coded segments ($n = 208$). This high prevalence suggests that managers perceive the success of AI adoption primarily through the lens of relational dynamics, specifically, how employees perceive, trust, and collaborate with automated systems in a high-touch service environment. As one manager emphasized, “people really value personal interaction... it is difficult to imagine a robot replacing that kind of communication” (P1), and, “for personal contact, there will always need to be a human factor” (P2).

Implementation Challenges followed as the second most frequent category ($n = 99$), representing 23.2% of the discourse. This reflects a pragmatic managerial awareness of the organizational and technical barriers that accompany digital transformation. Concerns about employee reactions were also evident, as one participant noted a “fear of the unknown” when introducing new technologies (P3). This concern is also reflected in managerial views on cost, as one participant noted that “the question is how high the costs of implementing such technology would actually be” (P1). Interestingly, while the Strategic Benefits of AI were frequently acknowledged ($n = 72$), they were discussed significantly less often than the human and operational challenges. Nevertheless, some managers still highlighted efficiency gains, noting that “it would make everything easier, since a robot does not make mistakes or delays tasks” (P1), and other improvements, with one stating that AI enables “faster processing and more accurate information” (P5).

The least prevalent theme was Required Competencies, which accounted for only 11.0% of the identified segments ($n = 47$). This relatively low frequency may indicate a critical gap in managerial awareness; while retail leaders are deeply concerned with how AI will be received by the workforce, they appear less certain about the specific skill sets and educational frameworks necessary to sustain such a transformation.

This uncertainty is reflected in managerial statements, as one participant noted that “managers would probably need some additional skills, but nothing too specific” (P6). At the same time, others emphasized the need for continuous adaptation, highlighting that “you have to keep up with the pace of AI development, otherwise you fall behind” (P2).

This distribution of themes underscores a socio-technical orientation where the human element remains at the forefront of the retail AI narrative.

4.3 Strategic Benefits and Implementation Challenges

The second phase of the findings focuses on the duality of AI integration, specifically the tension between anticipated strategic advantages and the practical hurdles identified by retail managers. This “dual-edged” perception is evident in the frequency of coded segments, where the promise of operational efficiency is frequently tempered by concerns regarding organizational readiness and resource

constraints. As one manager noted, AI can make processes “much easier and faster,” but at the same time “there are still many errors and uncertainties in how reliable these systems are” (P2).

Strategic benefits accounted for 16.9% of the managerial discourse ($n = 72$), with a primary focus on operational leanness and the automation of routine tasks. Managers identified process automation and inventory management as critical areas for high-value returns, frequently highlighting “smart orders” (*pametna naročila*) and “automated stock detection” (*zaznavanje izpraznjenih polic*) as essential tools for reducing human error and minimizing stockouts. As one participant explained, AI could significantly support inventory processes, particularly in complex supply chains where “it is difficult to manage stock levels due to the large number of products and suppliers” (P1). Beyond inventory, respondents emphasized the role of AI in resource optimization and operational ease, noting that technology significantly “eases the workload”. This is reflected in everyday use, as one manager explained, “it helps us a lot... especially when processing large amounts of data” (P2). Similarly, another participant highlighted that AI improves efficiency by making processes “faster and more accurate” (P5).

Finally, AI is perceived as a catalyst for customer experience enhancement through hyper-personalization. Managers envision smart systems, such as interactive kiosks or digital mirrors, providing customers with expert product information during peak hours, thereby maintaining service quality when staff availability is limited. This is illustrated by one manager’s observation that AI can provide customers with “more information in situations where staff are unable to assist everyone at the same time” (P1).

Implementation challenges were discussed more frequently than benefits ($n = 99$, 23.2%), indicating a cautious and pragmatic approach to technology adoption among retail leaders. These hurdles are categorized into distinct economic, technical, and psychological dimensions. Economic and technical constraints, particularly high initial capital investment, remain a significant deterrent, as managers expressed concerns regarding the “payback period” and whether efficiency gains would ultimately justify the substantial costs of hardware and software upgrades. This concern is reflected in managerial perspectives, as one participant noted that “the investment is quite high, and it is difficult to estimate when it would actually pay off”

(P4). This is compounded by technological skepticism, where several segments highlighted the "black box" nature of AI. Managers articulated a need for more transparent and explainable outputs, often citing a lingering concern regarding the accuracy of AI suggestions and noting that systems are still in a learning phase prone to errors. As one manager explained, "we still do not fully understand how the system makes decisions, which creates a lack of trust" (P3).

However, the most critical challenge identified was the human resistance factor, characterized by employee anxiety regarding job displacement. As one participant explained, "people are still not advanced enough to fully understand and trust these technologies" (P1). This concern is reinforced by broader fears about workforce impact, as another participant noted that "robots could replace jobs, which affects people's livelihoods" (P5). Managers emphasized that the "fear of the unknown" often leads to a lack of commitment during the initial rollout, which necessitates a robust focus on change management and transparent communication.

The interplay between these two themes suggests that while the strategic motivation for AI—driven by speed, precision, and cost-reduction—is clear, the path to implementation is heavily obstructed by human and financial considerations. This conceptual tension explains the frequent co-occurrence of these themes in managerial narratives, necessitating a deeper exploration of their structural relationship in the following analysis.

4.4 Co-occurrence Analysis and Mapping the Interplay Between Themes

While the prevalence of individual themes provides a baseline for understanding managerial focus, the co-occurrence analysis reveals the underlying structural logic of how retail leaders conceptualize AI integration. By employing the Code Relations Browser in MAXQDA, the researcher mapped the intersections of thematic categories within the same coded segments. The resulting matrix, visualized in Figure 3, identifies several critical "gravity centers" in the managerial narrative.

The most prominent intersection (indicated by the largest intersection square in the matrix) occurs between Human–Technology Interaction and Implementation Challenges. This co-occurrence is analytically relevant; it indicates that when retail managers discuss the difficulties of adopting AI, they frequently link these hurdles

to the human factor. The challenges of cost or technical integration are rarely discussed in isolation; instead, they are framed within the context of employee trust, workplace adaptation, and the potential disruption of established social dynamics within the store. This suggests that for managers, the "problem" of AI is inherently a socio-technical one.

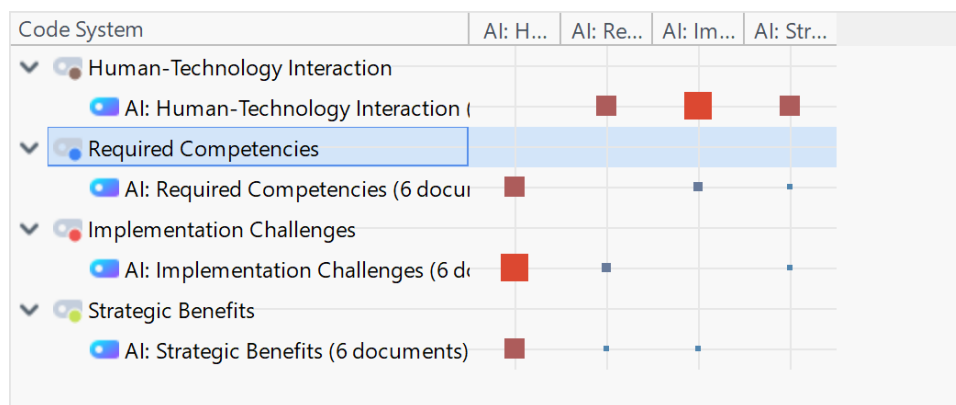


Figure 3: Code Relations Matrix Visualizing Thematic Intersections

Source: own.

A second significant pattern is the co-occurrence of Strategic Benefits and Human–Technology Interaction. This link demonstrates that managers perceive the value of AI—such as efficiency gains and automated inventory management—as being strictly contingent upon how employees interact with the technology. In managerial narratives, the "benefit" only materializes if the human-AI collaboration is well-coordinated. For example, the benefit of a "smart shelf" system is only realized if the staff trusts the automated alert and acts upon it efficiently.

Conversely, the matrix reveals a relatively weak link between Strategic Benefits and Required Competencies. This is a critical finding, as it suggests a conceptual disconnect: while managers recognize the strategic value of AI, they do not yet strongly associate these gains with the necessity of a specific upskilling or reskilling agenda.

Mapping these interplays suggests that the retail manager's perspective is fundamentally human-centric. The successful transition to a "phygital" retail environment is not seen as a triumph of software over manual labor, but as a

complex renegotiation of the relationship between the staff, the technology, and the operational goals of the organization.

5 Discussion

The findings of this study provide a nuanced understanding of how retail managers in Slovenia perceive AI, effectively bridging the theoretical concepts of "phygital" ecosystems (Belghiti et al., 2018) with operational reality. A central tension identified in the results is the balance between technological efficiency and the preservation of "human warmth." While Grewal et al. (2017) emphasize that AI should complement rather than disrupt the store experience, participants in this study (particularly P4 and P5) expressed a more protective stance over human interaction. This suggests that in some retail contexts characterized by a stronger emphasis on personal interaction, the "human-AI symbiosis" proposed by Wilson and Daugherty (2018) may be perceived not as a balanced distribution, but as a dynamic where human empathy remains the primary factor.

Regarding the strategic benefits, the managerial focus on inventory optimization and demand forecasting (P1, P3, P6) strongly supports the predictive analytics frameworks discussed by Oosthuizen et al. (2020) and Petropoulos et al. (2018). However, while Brynjolfsson and McAfee (2014) argue for a transition to purely data-driven choices, Slovenian managers still maintain a high degree of "intuition-based" decision-making, particularly when AI systems fail to account for local market nuances. The reported inefficiency of robotic systems (P5) and AI-generated errors in training (P4) provide empirical evidence for the "technological inadequacies" and "fragmented data" issues warned about by Balchandani et al. (2020) and Woudberg (2022).

The generational divide emerged as a critical factor that is often understated in broad strategic literature. While Arora et al. (2021) discuss hyper-personalization as a tool for revenue growth, our findings (P2, P5) indicate that for older demographics (60+), AI-driven personalization may trigger privacy anxieties rather than loyalty. This reflects the "black box" dilemma and privacy risks highlighted by Mazurek and Malagočka (2019). The resistance noted by managers aligns with the workforce anxieties described by Frey and Osborne (2017), yet our data suggests that "soft skills"—empathy and critical thinking—are not just future competencies but are

currently being used as a strategic buffer to maintain consumer trust during the digital transition, as theorized by Morandini et al. (2023).

The thematic synthesis of this study, supported by visual co-occurrence mapping and code frequency analysis in MAXQDA, provides empirical confirmation of the theoretical frameworks regarding AI's strategic imperative in retail (Oosthuizen et al., 2020). Specifically, the high intensity of the "Human–Technology Interaction" category across all cases, especially in the narratives of P4 and P5, supports Grewal's (2017) assertion that AI must complement rather than disrupt the traditional in-store experience. Furthermore, the co-occurrence analysis suggests a link between "Implementation Challenges" and "Required Competencies," indicating that managers sometimes refer to technological limitations—such as those reported in automated logistics (P5) and AI training errors (P4)—in connection with the continued importance of human judgment and skills. These segments do not imply a direct causal relationship but rather highlight how such challenges are discussed alongside reflections on human capabilities. This can be interpreted as aligning with the broader shift toward uniquely human "soft skills" emphasized by Stefano Morandini et al. (2023). At the same time, the relatively weaker connection between strategic benefits and required competencies suggests a possible gap in managerial awareness regarding systematic upskilling and reskilling. This intersection suggests that while Wilson and Daugherty (2018) theorize a seamless human-AI symbiosis, the operational reality in the Slovenian retail market remains a "cautious integration," where managers act as essential mediators to mitigate the perceived coldness of automated systems and address the "black box" dilemma identified by Mazurek and Malagocka (2019).

The findings of this study contribute to the existing literature on AI in retail in several important ways. The results extend prior research that has predominantly focused on technological capabilities and operational efficiency (Grewal et al., 2020; Haque et al., 2024) by demonstrating that managerial perceptions are strongly shaped by socio-technical considerations. In particular, the dominance of human–technology interaction highlights that AI adoption in physical retail is not merely a technological implementation process, but a relational and organizational transformation. This study also provides empirical evidence that managerial discourse is characterized by a clear tension between perceived strategic benefits and implementation challenges. While existing literature often treats these dimensions

separately, the findings show that managers experience them simultaneously, suggesting that AI adoption should be understood as a dynamic balancing process rather than a linear transition. Additionally, the relatively low emphasis on required competencies reveals a potential blind spot in managerial thinking, indicating that skill development and organizational learning may be underprioritized in early stages of AI adoption. This insight contributes to the growing discussion on the human capital implications of digital transformation (Woudberg, 2022; Ukwuoma, 2025).

Taken together, these findings reinforce the view that AI integration in physical retail is best understood as a socio-technical process in which technological, organizational, and human factors are deeply intertwined.

5.1 Managerial Implications

The findings of this study provide several important managerial implications for retail organizations implementing AI technologies. First, the dominance of human–technology interaction in managerial discourse highlights the critical importance of effectively managing employees during the AI adoption process. Managers should not treat AI implementation solely as a technological upgrade, but as a change management process that requires clear communication, employee involvement, and trust-building. Addressing employee concerns, particularly the fear of job displacement, emerges as a key priority for ensuring successful adoption.

Second, the observed tension between strategic benefits and implementation challenges suggests that AI integration should be approached incrementally rather than through large-scale, immediate transformation. A phased implementation strategy allows organizations to test solutions, reduce uncertainty, and gradually build internal acceptance. This is particularly important in environments such as physical retail, where operational disruptions and employee resistance can significantly affect customer experience.

Third, the relatively low emphasis on required competencies indicates that retail organizations may underestimate the importance of skill development in the context of AI adoption. Managers should therefore prioritize both technical and non-technical competencies. While digital literacy and data understanding are essential for interacting with AI systems, soft skills—such as adaptability, communication, and

critical thinking—are equally important for navigating socio-technical change and collaborating with intelligent systems.

Finally, the findings suggest that AI should be implemented as a complementary tool that enhances, rather than replaces, human interaction in physical retail. Given the central role of personal contact in in-store environments, managers should focus on integrating AI in ways that support employees and improve customer experience without undermining the relational aspects of retail service.

5.2 Limitations and Future Research

Despite the depth of the qualitative insights, this study is subject to certain limitations. The sample size of six managers, while sufficient for exploratory qualitative research and providing sector diversity, does not allow for statistical generalization across the entire Slovenian retail market. This limitation is particularly relevant given the specific characteristics of the Slovenian retail context. Slovenia represents a relatively small, highly service-oriented economy, where retail activity is predominantly embedded in local markets and closely tied to small and medium-sized enterprises (SMEs) (OECD, 2024). The sector is characterized by a high share of smaller firms, including family-owned businesses, which often operate with limited financial and technological resources and may therefore adopt digital innovations more gradually (EY, 2015). Although the sample includes managers from different retail sectors, the study does not allow for systematic comparison between sectors due to the small number of participants. The sectoral diversity was intended to capture variation in retail contexts rather than to support sector-specific conclusions.

At the same time, the Slovenian retail environment is shaped by strong local customer relationships and a traditionally high emphasis on personal interaction in service delivery. These structural and cultural characteristics may influence how managers perceive and implement AI technologies, particularly in terms of employee interaction, trust, and customer experience. As such, the findings of this study should be interpreted within this specific context and may not be fully generalizable to larger or more technologically advanced retail markets. Furthermore, the findings are based on self-reported managerial perceptions, which may differ from the actual lived experiences of frontline employees or the direct reactions of customers.

Future research should address these gaps by employing longitudinal designs to examine how managerial perceptions evolve as AI systems become more embedded in daily retail operations. Future studies could explore differences across organizational scale, comparing small and medium-sized retailers with large multinational retail chains, to better understand how resource availability and organizational complexity influence AI adoption and implementation challenges. Additionally, further research should consider sector-specific dynamics within retail, as the relevance and application of AI may vary significantly between industries such as fashion, food retail, and specialized product segments. This would provide a more nuanced understanding of how contextual factors shape managerial perceptions and strategic priorities. Importantly, future studies should incorporate the perspective of front-line employees, who directly interact with both customers and AI systems in physical retail environments. A bottom-up approach would allow for a deeper understanding of workforce adaptation, resistance, and the practical implications of human–technology interaction in everyday operations. Finally, comparative cross-country studies would be valuable in identifying how institutional, cultural, and economic differences influence AI adoption in retail. Extending the analysis beyond managerial perspectives to include customer viewpoints would further enrich the understanding of how AI affects the retail experience in "phygital" environments.

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Summary

This research investigates managerial perceptions of artificial intelligence (AI) integration in physical retail environments, focusing on the Slovenian market. Through six semi-structured interviews with managers from diverse sectors, the study identifies a significant tension between the drive for technological efficiency and the fundamental need to preserve "human warmth" and empathy in-store. Utilizing MAXQDA for thematic and co-occurrence analysis, the findings reveal that while managers recognize the strategic benefits of AI, such as inventory optimization and data-driven decision-making,

they face substantial implementation hurdles, including technological inadequacies, high costs, and demographic resistance from older consumer segments. The results underscore the necessity for a "hybrid intelligence" approach, where AI augments rather than replaces human staff. Furthermore, the study highlights a critical gap in managerial focus regarding the specific upskilling and reskilling strategies required for a successful digital transition. Ultimately, the research suggests that the future of "phygital" retail depends on the orchestration of a seamless human-AI symbiosis that maintains the relational value of the physical shopping experience.

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FINANCIAL HEALTH OF LOCAL GOVERNMENTS AND ITS CONNECTION WITH ESG

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The chapter examines the relationship between ESG factors and the credit risk of Slovak municipalities. We assume that the financial profile of a municipality cannot be fully understood from its financial statements alone, and that the environment in which it operates is an equally important part of the assessment. Our dataset includes four financial indicators, namely debt, liquidity, economic margin and debt service, the unemployment rate as a social indicator and three environmental air quality indicators, namely PM10, PM2.5 and NO2. Factor analysis identifies the hidden structure of relationships among variables and extracts four components that explain 81.5% of the total variability. The first component links the concentrations of PM10 and PM2.5 particulate matter to municipalities' indebtedness, indicating a common dimension of environmental burden and financial risk. Discriminant analysis classifies municipalities into two groups: those with problem debt and those without. The key variables differentiating the groups are economic margin, liquidity and debt service. The structural matrix also shows that the environmental variables PM2.5 and NO2 exhibit a stronger direct connection with the discriminant function than most financial variables, confirming their additional information value.

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1 Introduction

Interest in non-financial factors affecting the financial stability of public administrations has grown significantly in recent years. Climate change, air pollution, demographic pressures, and the quality of governance processes are increasingly recognised as measurable factors that directly affect public entities' ability to meet their obligations. The European Banking Authority (EBA, 2025) has explicitly included environmental (E), social (S), and governance (G) risks (ESG) among the areas that must be systematically integrated into risk management. This regulatory change confirms that ESG factors are moving from a voluntary sustainability framework to a mandatory credit risk assessment tool. Most of the existing literature focuses on the relationship between ESG and credit risk at the state or corporate level.

Territorial self-government, i.e., municipalities and cities, remains relatively on the sidelines in this discussion. However, they are the ones that face climate shocks, social pressures, and investment requirements directly at the local level. Bruno and Henisz (2022) state that local governments are in a different position regarding ESG outcomes. Local governments differ in the environmental, social, and governance (ESG) outcomes they provide to their residents. Primarily, this concerns the composition of toxic emissions, the social environment, and residents' health status. These outcomes are mainly related to the quality of life of residents in a specific geographic area and go beyond standard indicators of financial health. The policies, expenditures, and revenue practices of local governments vary in the priority they assign to these ESG outcomes. It appears that municipalities' willingness to monitor and address environmental, social, and governance issues in their localities will lead people to migrate to regions with lower pollution, better schools, better health outcomes, greater safety, etc. As a result of these changes, local governments that improve their citizens' quality of life will be rewarded with increased tax revenues, which they can then use to support sustainable investments in public services. Bruno and Henisz (2024) showed that ESG characteristics of a territory are associated with lower credit risk of municipal debt. Cappiello et al. (2025) demonstrate that physical climate risks reduce credit ratings by affecting public budgets.

This chapter conceptualises ESG pillars as a framework for assessing non-financial risks with potential financial impacts. We explore the transition of these factors into credit risk, with a specific focus on the municipal context and the methodological landscape of the Slovak Republic. Our empirical approach employs factor analysis to examine the interactions among environmental, social, and financial metrics. We used discriminant analysis to confirm whether the proposed financial, environmental, and social indicators allow classification of municipalities based on their credit profiles. Finally, the chapter demonstrates why ESG integration is essential for assessing the long-term financial resilience of local governments.

2 ESG pillars

As was established by the European Commission (2023), ESG pillars serve as a framework for organising sustainability topics into three distinct domains: environmental (E), social (S), and governance (G).

The environmental pillar (E) specifically addresses the protection of the natural world, along with relevant impacts and risks. Within the framework of the European Sustainability Reporting Standards (ESRS), this area is operationalised through thematic standards covering (European Commission, 2023): climate change, pollution, water and marine resources, biodiversity and ecosystems, and the Use of resources in the transition to a circular economy.

According to the European Commission (2023), the social pillar (S) focuses on impacts on people and society, as well as issues related to the groups involved. In the social field, ESRS distinguishes four thematic standards according to which the social topics are related: own workforce, workers in the value chain, affected communities, consumers and end users.

The governance (G) pillar refers to governance and control rules, as well as to how the organisation establishes and applies governance, integrity, and oversight processes. ESRS in the field of governance use thematic standard G1 - business conduct, which covers issues of behaviour, ethics and rules that affect the integrity of decision-making and the trustworthiness of the organisation.

The pillars defined in this way are also associated in the literature and standards with a financially significant perspective, i.e., the fact that sustainable risks and opportunities can affect the entity's economic functioning. According to the standard S1 of the International Financial Reporting Standards (IFRS) (IFRS Foundation, 2023, p. 6), issued by the IFRS Foundation, formulates this link explicitly: "the standard requires that the entity, including municipalities, disclose information about all sustainable risks and opportunities that can reasonably be expected to affect the entity's cash flows, its access to financing or the cost of capital over various time horizons".

The ESG concept provides a systematic framework for integrating environmental, social, and governance factors into municipal financial decision-making, risk management, and reporting transparency. ESG has evolved into a cornerstone of the capital market's information infrastructure, with investors increasingly relying on sustainability data to evaluate local government stability. As noted by Christensen, Serafeim, and Sikochi (2021), integrating ESG metrics into investment decisions serves as a critical tool for identifying risks and opportunities in municipal financing. Consequently, lenders now utilise this information to determine the creditworthiness and long-term viability of municipal entities.

ESG is also linked to organisations' risk management and internal governance processes. In a risk-averse regulatory environment, ESG is recognised as an essential component that local governments must address alongside traditional risk management functions. To ensure consistency, the European Banking Authority (EBA, 2025) has established reference methodologies for identifying, measuring, and monitoring ESG risks. For municipalities, adopting these standards means embedding sustainability into the core of their administrative oversight and long-term financial planning.

According to the European Commission (2023), ESG is also related to transparency and reporting, as it is materialised in practice through standardised disclosure frameworks. In the European ESRS environment, these structures enable long-term comparability and consistency of information across the public sector. For local authorities, this framework serves as a formal communication channel. By adhering to these disclosure standards, municipalities can provide reliable information to

institutional lenders and stakeholders, ensuring that sustainability efforts are documented in a globally recognised and verifiable format.

Despite the growing use of ESG in practice, the literature emphasises the need to distinguish between the concept of ESG itself and the specific products of providers, especially ESG ratings. Christensen, Serafeim, and Sikochi (2021, p. 6) note the empirically observed discrepancy between ratings from different providers. For municipalities, this means that increased transparency does not inherently lead to a consensus on their sustainability standing. Instead, divergent methodological choices and interpretive frameworks among providers can result in varying assessments of a local government's creditworthiness and ESG performance.

A significant part of this methodological ambiguity stems from the fact that ESG ratings lack a single "subject" of assessment, as we know it for credit ratings. The authors Berg, Kölbel and Rigobon (2022, p. 1335) subsequently explain that the differences between ESG rating providers can be analytically decomposed into differences in the scope of the assessed topics (scope), in the way the same attributes are measured (measurement) and in the weighting of individual categories (weight). In their empirical results, measurement dominates on average, contributing 56%, scope 38%, and weights 6%. It means that the differences in ratings are not only a question of which areas are monitored, but also of how the same areas are quantified.

The discrepancy in ESG ratings also has market implications for public entities. Gibson, Krueger, and Schmidt (2021, p. 8) report that their analysis shows a positive association between the discrepancy in ESG ratings and returns. Therefore, the risk premium of a company with a higher discrepancy in ESG ratings is higher. In addition, Christensen, Serafeim and Sikochi (2021, p. 35) found, when testing market implications, that the discrepancy is positively associated with return volatility and absolute price movements. They also document a connection with a lower probability of obtaining external financing. For municipalities, these findings support the conclusion that methodological transparency is essential when working with ESG ratings. Therefore, in empirical applications, it is appropriate to directly state the source of the rating used, the method of construction and the limitations of its interpretative comparability.

2.1 ESG factors as sources of non-financial risk

In the literature on public finance risks, environmental, social, and governance factors are increasingly recognised as non-financial sources of shocks that can impact budgetary stability and an entity's ability to meet its obligations. According to the Organisation for Economic Co-operation and Development (OECD) (2024, p. 3), fiscal risks in public budgets, including local government budgets, manifest as deviations in revenue and expenditure from the plan and arise not only from macroeconomic fluctuations but also from institutional weaknesses and unforeseen liabilities. As the OECD states in its publication *Managing rising subnational fiscal risks*: "Risks can also arise from weaknesses in budgetary institutions and processes or from the materialisation of contingent liabilities that were not included in the budget." In the same text, the OECD emphasises that frequent or large materialisations of risks can "threaten fiscal sustainability as well as the efficient provision of essential public goods and services to the population." This framework applies to municipalities because their financial stability is tied to the continuity of public services (operations, maintenance, and investments). At the same time, they are exposed to local shocks of environmental, social, or governance origin.

The most visible group of non-financial risks is physical environmental risks, i.e., the impacts of extreme events and long-term climate trends on people, infrastructure, and public services. The UN Intergovernmental Panel on Climate Change (IPCC, 2022, p. 8) points out in its summary for policymakers that we are already observing extensive negative impacts and losses due to climate change, and that the growth of extremes is pushing systems beyond the limits of adaptation. At the local level, this typically means a higher risk of costs for interventions, repairs, and the restoration of municipal assets, such as local roads, bridges, and public buildings, as well as pressure on services, such as crisis management, social assistance, and temporary accommodation. The OECD (2024, p. 6) directly notes the trend of increasing disaster intensity and frequency. As a result of climate change, there has been a significant increase in weather-related natural disasters, including droughts, floods, hurricanes, and fires. Regarding the division of competences, the OECD adds that supranational governments are, in practice, involved in immediate assistance, the restoration of basic public services, and the reconstruction of affected infrastructure. These mechanisms represent typical channels through which an environmental shock becomes a budgetary shock, mainly through one-off expenditures and a shift

in investment priorities. However, environmental risk is not only about disasters; chronic environmental pressures that impact the health of the population and the quality of life also play a significant role. In European conditions, air quality, characterised by the indicators PM10, PM2.5, and NO2, is most often discussed. The European Environment Agency, hereinafter referred to as EEA (2024, p. 1), states in its review Europe's air quality status 2024 that "96% of the EU urban population is exposed to hazardous concentrations of fine dust particles (PM2.5). In the context of local air quality policy, these findings can be interpreted as potential pressure on preventive and investment measures.

Social risks are often described in the public finance literature as sources of expenditure pressure, revenue shortfalls and the risk of rising liabilities. In the same document, OECD (2024) also includes public health and demographic trends among the growing fiscal risks, noting that health and long-term care spending are increasing and that budgets are under pressure, even as revenue changes. The OECD states that public health budgets may also face pressure because population ageing reduces the share of workers and, in turn, the tax base, particularly in systems linked to contributions and taxes. At the same time, the OECD directly links health risks to environmental degradation and climate change, including the risk of zoonotic diseases, thereby strengthening the argument that social and environmental factors intersect in practice. Governance risks in the context of public finance are described mainly through the quality of budgetary processes, control mechanisms and the ability to anticipate and cover contingent liabilities. OECD (2024, p. 3), therefore, includes weaknesses in budgetary institutions and processes, as well as the materialisation of contingent liabilities, as sources of fiscal risk. For municipalities, this channel can be practically visible, for example, in overvalued investment projects, in weak financial planning, in postponing maintenance, which increases future capital expenditures, or in the incorrect setting of contractual obligations, which subsequently turn into unexpected expenses. The financing aspect is also important, since a significant part of the supranational debt is in the form of bank loans and short-term instruments, which increases sensitivity to interest rate risk. Although the specific parameters vary by country, the logic is general: the combination of weaker processes and a riskier financing structure increases the likelihood of budgetary deviations and the accumulation of liabilities.

2.2 Linking non-financial risks to credit risk

In recent years, the nexus between non-financial risks and the credit profiles of public entities has gained prominence, particularly in the context of climate change. Cappiello et al. (2025) demonstrate that temperature anomalies and frequent natural disasters correlate with lower credit ratings, driven by a clear transmission mechanism: both physical and transition risks necessitate increased public spending on subsidies and disaster relief, which escalates municipal debt and erodes creditworthiness.

According to the EEA (2024), these risks manifest in municipalities as multifaceted pressures: expenditure shocks from reconstruction (sudden costs for emergency repairs and social assistance), investment pressures for climate adaptation (required funding for infrastructure adaptation and air quality improvement), revenue risks (potential erosion of the tax base due to shifts in the local economy or migration), and governance risks related to debt structures or exposure from contingent liabilities and sub-optimal debt management. Consequently, monitoring environmental data (e.g., PM10, PM2.5, NO2), social indicators (e.g., unemployment), and fiscal metrics is a vital methodological approach for quantifying how non-financial factors jeopardise a municipality's financial stability.

3 Credit risk and municipalities

Credit risk presents a fundamental challenge in the financial landscape, particularly regarding a debtor's—such as a municipal entity's—ability to fulfil financial commitments. As stated by the ECB (2026), the risk is that a counterparty fails to settle a loan in full at the scheduled maturity. This definition highlights that for local governments, credit risk encompasses both the ultimate default and the specific timing of performance. From a management perspective, municipalities can address this by using metrics such as probability of default (PD) and expected loss (EL), aligning qualitative assessments of fiscal health with quantitative risk and credit valuation.

The link between asset quality and institutional stability makes credit risk a permanent priority for municipal financial oversight. While the European Court of Auditors (2023) focuses on banks, the principle remains identical for local

authorities: failure to service Debt leads to a loss of viability. A municipal loan or guarantee is generally considered non-performing if the obligations are more than 90 days past due. In line with EBA (2020) guidelines, municipalities should establish robust policies for identifying, assessing, and mitigating credit risk within their internal procedures. We can say that it is necessary to ensure that credit risk is not only considered as a pressure on the budget (interest margins) but also as a solvency risk (capital adequacy and loss coverage), which requires disciplined monitoring of signals of non-compliance to avoid sharp financial losses.

Regulation plays a crucial role in municipal credit risk assessment, aiming not only to measure risk but to ensure it is managed within statutory debt limits and supported by adequate fiscal reserves. Following the logic of the European Court of Auditors (2023), municipal oversight functions similarly to the Supervisory Review and Evaluation Process (SREP), verifying that sufficient budgetary buffers cover a local government's risks. Within this framework, credit risk is a key component of fiscal stability. As per the ECB's (2023) methodology, assessing a municipality's credit risk combines a quantitative analysis of debt levels—such as debt-to-revenue ratios—with a qualitative evaluation of governance. Consequently, risk is conceptualised as a combination of the municipality's current financial obligations and the effectiveness of the administrative processes governing them.

The significance of credit risk for the public sector is reflected in the need for comparability and consistency in the models used to assess municipal fiscal health. Drawing on EBA (2025) principles, oversight bodies should benchmark local governments to identify significant deviations from peer institutions. If a municipality's internal risk assessment leads to an underestimation of debt-related risks that its underlying economic conditions cannot justify, corrective measures must be taken. Methodological transparency is essential, as credit risk is a fundamental input in determining credit terms, risk premiums, and the overall availability of financing for local authorities.

3.1 Methods of assessing the financial health and credit risk of Slovak municipalities

The Council for Budget Responsibility (RRZ, 2025) describes the assessment of municipalities' financial health in Slovakia. The Council for Budget Responsibility (RRZ, 2025) has established procedures to determine whether a municipality can meet its long-term obligations, finance public services, and maintain budgetary stability without excessive debt and past-due liabilities.

From the perspective of a creditor, such as a bank or investor, the core of the assessment is credit risk, i.e. the probability that the municipality will not be able to repay its obligations properly and on time. In practice, Slovak municipalities mainly apply approaches based on regulatory limits and supervision, a set of financial indicators from accounting and budget statements, synthetic indices or scoring models that aggregate multiple indicators into a single result.

A very important group consists of the rules and limits embedded in the local government's fiscal framework. These limits serve as thresholds that enable rapid identification of municipalities with an increased risk of excessive indebtedness or excessive debt service. In Slovakia, the Council for Budget Responsibility (RRZ, 2025) defined the threshold at 60% of the previous year's current revenues. Failure to comply with it will result in fines being imposed on local governments. The significance of regulatory limits is not only punitive; they also serve a preventive role by setting a maximum debt limit relative to the local government's current revenue capacity. The Council for Budget Responsibility also explains the logic of linking rules to current revenues so that local governments can realistically cover their liabilities with their current operations. For financial health research, it is therefore natural to work with indicators of debt, debt service, liabilities, and the revenue base, as these quantities serve as the basis for the formal assessment of municipal fiscal discipline.

Another key approach to assessing financial health uses financial health indicators derived from financial statements and budget management. It is a method that does not provide a simple "meet/fail" result, as with limits, but allows for more nuanced diagnostics, for example, capturing a combination of growing past-due liabilities, low liquidity and a deteriorating operating balance, which may signal future problems

even before legal thresholds are exceeded. In the academic literature, the financial performance and financial situation of municipalities are often evaluated using multiple indicators, and municipalities are then classified into relatively homogeneous groups. The authors Lukáč et al. (2021) use a set of financial indicators to assess local governments and employ multidimensional approaches to distinguish groups of municipalities with different financial situations, emphasising that the indicators can capture differences between local governments even within a single region. According to the Institute for Economic and Social Reforms, hereinafter referred to as INEKO (2024, p. 31), in connection with the practice of Slovak local governments and the availability of data, the most used diagnostic indicators include:

- total debt and its relationship to current income,
- debt service (principal and interest payments) in relation to income,
- current account balance (continuous management), as an indicator of the ability to finance operations without pressure on Debt,
- past-due liabilities, as a signal of payment discipline,
- Liquidity, such as cash, is a short-term ability to pay liabilities.

The third important approach is synthetic indices and scoring methodologies, which convert multiple indicators into a single composite score. Their benefit is clarity and comparability between municipalities, while the disadvantage may be sensitivity to the chosen methodology. In the Slovak environment, a well-usable example is the financial health methodology published in the analytical outputs of the *hospodarenieobci.sk* portal, which transparently describes what the resulting score consists of. The resulting overall score describing the financial health of cities is a weighted average of the 5 partial scores obtained using weights of 30%, 10%, 30%, 15% and 15%, respectively, for total debt, debt service, current account balance, past due liabilities and liabilities more than 60 days past due.

Radebe, Nomlala, and Matenda (2025) state that there are also models aimed at early identification of financial distress, or “early warning,” using indicators and composite indices. These approaches are often constructed as classification models that, based on a combination of financial ratios and thresholds, classify entities into “safe-grey-risk” zones. A systematic review of the literature states that several types

of models are used in local governments, including discriminatory approaches, logistic models and scoring frameworks, while in practice, threshold rules are often applied to interpret the result. At the same time, it should be noted that local governments have their own specificities. Their goal is to provide services; they have a different income and expenditure structure, and political factors influence them. Piermarini et al. (2023) state that it is methodologically appropriate to adapt the scoring or Z-score to the available data. At the same time, the Z-score should be interpreted with caution as an indicator of relative risk rather than an exact prediction of failure.

4 Linking ESG factors and credit risk

The link between ESG factors and credit risk is based on the thesis that environmental, social, and governance factors, particularly in the form of shocks, trends, and weaknesses in public administration, are reflected in traditional financial risks over time and can ultimately affect the borrower's ability to meet its obligations. EBA (2025) formulates this relationship as: "ESG risks can affect all traditional categories of financial risks to which institutions are exposed." In the same document, the EBA emphasises that ESG risks should be understood "as potential causes of all traditional categories of financial risks, including credit risk." In the local government environment, the link between ESG and credit risk primarily manifests through public finances. ESG factors affect the likelihood of deviations of revenues and expenditures from planned levels, and thus the stability of the budgetary position. Authors de Mello and Ter-Minassian (2024, p. 2) define fiscal risks as "events whose realisation leads to significant deviations of revenues and expenditures from budgeted amounts." The document states that sources of increasing fiscal risks include structural changes, such as those driven by climate change. From a credit risk perspective, it is crucial that the materialisation of these risks can "threaten fiscal sustainability, as well as the efficient provision of basic public goods and services." For Slovak municipalities, this framework is applicable as a theoretical justification for why it is legitimate to examine ESG variables such as air quality, social situation, or elements of governance and transparency in conjunction with indicators of financial health and indebtedness, the risk channel leading through budgetary resilience and the ability to absorb shocks without worsening payment discipline.

Regulatory frameworks increasingly emphasise that credit risk is a natural target for integration with environmental and climate factors, particularly. The Basel Committee on Banking Supervision (BCBS, 2021) states in its principles for managing climate-related financial risks that banks should understand the impact of climate-related risk factors on their credit risk profile and ensure that credit risk management systems and processes take significant climate-related financial risks into account. In this sense, when a local government seeks financing, lenders must identify and measure how climate factors influence the municipality's credit exposure.

It follows from the above that the connection between ESG and credit risk extends beyond physical risks. The governance pillar, i.e. the quality of decision-making and control mechanisms and their anchoring in risk management, also has a significant role. The European Central Bank (2022), in its compendium of good practices for managing climate and environmental risks, emphasises that the assessed institutions should build and align risk management strategies and processes to meet expectations. The document thus emphasises the logic of the connection between ESG and credit risk and shows how non-financial risks are incorporated into management processes. If the governance pillar is weak, for example, there is a lack of systematic risk identification, internal control mechanisms, planning and monitoring, the likelihood that ESG shocks and trends will be reflected in financial indicators faster and with higher losses increases. In the municipal environment, this argument is transferable in principle; the quality of financial management and control processes determines how quickly and accurately a local government can recognise and mitigate the budgetary consequences of environmental and social stimuli.

Empirical support for a direct link between ESG characteristics of a territory and credit risk is provided by the work of Bruno and Henisz (2024) from the field of municipal finance. The authors state that collective improvements in community ESG factors are associated with a reduction in the credit risk of municipal financial instruments over time. They also present the result in terms of the price of risk. They state that more aggregated ESG results are associated with lower credit returns for municipal financial securities. ESG is not evaluated solely as a company feature, but as a set of results and characteristics of the territory, which are subsequently associated with the credit risk of a public issuer or borrower. This concept is

conceptually compatible with the empirical part for municipalities, where environmental and social indicators, such as air quality and unemployment, represent measurable characteristics of the territory, and the municipality's financial statements allow for approximating credit quality through financial health models.

5 Analysis of ESG and financial indicators of the Slovak municipalities

The empirical analysis focuses on Slovak municipalities, and cities/villages are viewed from two perspectives. As economic units, their financial health depends on budgetary stability, indebtedness, liquidity, and payment discipline, all of which are measurable through public financial statements. At the same time, territorial units, where each municipality operates in a geographical and socio-economic environment with different air quality and unemployment rates. This dual perspective provides the basis for integrating both financial and environmental-social variables into a single analytical framework, an approach consistent with Bruno and Henisz (2024), who view ESG as a set of measurable characteristics of the territory rather than an attribute of the organisation itself.

Slovak municipalities are anchored in the fiscal framework set out in the Act on Budgetary Responsibility. The Council for Budget Responsibility (RRZ, 2025) defines the legal debt limit as 60% of the previous year's current income. This regulatory framework defines when a municipality can be considered risky from a formal perspective and is therefore part of the institutional context of credit risk assessment.

We have used publicly available data from three independent institutional sources. In comparison, the analytical set consisted of 34 municipalities with complete records for the reference year 2024. Financial data come from the Finstat database (2026). The source is the balance sheets and income and expenditure statements for the financial year 2024. Four ratio indicators were calculated from the items of these statements in accordance with the diagnostic recommendations of INEKO (2024) and RRZ (2025):

- Indebtedness (Indebtedness) - the ratio of total liabilities to the total value of assets.
- Liquidity (Cash) - the ratio of available cash to total assets.

- Economic margin (Margin) - the ratio of the difference between income and expenses to total income.
- Debt service (Debt Service) - the ratio of financial expenses to total income.

Environmental data are from measurements of the Slovak Hydrometeorological Institute (SHMÚ, 2026) for 45 Slovak municipalities. The average annual values for 2024 were used for PM10, PM2.5 and NO2. In municipalities with multiple measuring stations, the average of the stations was calculated. The management pillar (G) is not represented in the analysis due to the unavailability of quantitative management indicators at the municipal level in the Slovak public sources for the monitored period. Social data and the unemployment rate are from the website of the Central Office of Labour, Social Affairs and Family provider (UPSVaR, 2026). For each municipality, the annual average was calculated from the monthly values for the year 2024.

The average debt of the municipalities in the sample is 13.4%, which is significantly below the legal limit of 60% of current revenues (RRZ, 2025) (see Table 1). However, the 9.1% standard deviation indicates significant heterogeneity, suggesting that debt levels differ substantially across municipalities. The liquidity indicator is generally low, averaging 6.9%, consistent with common values in public administration, where excess cash is not a strategic goal. The economic margin is only 2.2%, indicating very tight operating management in most of the monitored municipalities. Debt servicing is on average 1.9%, but the standard deviation of 4.3% indicates that some municipalities pay a significantly higher share of income on instalments. The unemployment rate fluctuates significantly across the sample, reflecting regional differences in job availability and municipal tax capacity. Among the environmental indicators, PM2.5 is noteworthy, with an average value of 14.3 $\mu\text{g}/\text{m}^3$ significantly exceeding the WHO guideline value (5 $\mu\text{g}/\text{m}^3$), which is in line with the EEA (2024) findings for most European cities. The significant standard deviation of NO2 (6.6 $\mu\text{g}/\text{m}^3$) suggests that this indicator is more heterogeneous in the sample than the PM fractions. The different traffic and industrial conditions at individual locations cause it.

Table 1: Descriptive Statistics

	Indebtedness	Cash	Margin	Debt Servis	Unemployment	PM10	PM2.5	NO2
Mean	0.134	0.069	0.022	0.019	0.037	20.588	14.265	12.71
Std. Dev	0.091	0.047	0.056	0.043	0.02	3.627	3.028	6.599

Source: own

Based on the Kaiser criterion, four components were extracted, explaining together 81.5% of the total variability. Details are given in Table 2. Before rotation, the first component captures 36.5% of the variability. After Varimax rotation, the loadings are more evenly distributed, and the components capture 26.7%, 22.4%, 18.3%, and 14.1% of the variance. The total share of 81.5% is preserved, and the rotation only facilitates substantive interpretation by ensuring that each component corresponds to a single analytical dimension.

Table 2: Variability of the extracted components

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	2.924	36.544	36.544	2.134	26.677	26.677
2	1.868	23.354	59.898	1.789	22.362	49.039
3	0.936	11.706	71.604	1.467	18.338	67.377
4	0.793	9.913	81.517	1.131	14.140	81.517

Source: own

Table 3 shows the results of the factor analysis. Environmental burden and Debt represent the first component. PM10 (0.846) and PM2.5 (0.833) clearly dominate in the first component. Their strong mutual correlation is physically predictable; PM2.5 is a subset of PM10. More remarkable is the debt result (0.714), which is included in the same dimension as the environmental variables. This pattern suggests that municipalities with a higher particulate matter burden also show higher debt levels, which can be interpreted through the mechanism described by OECD (2024): environmental shocks (floods, infrastructure rehabilitation) generate one-off expenditure pressures that municipalities address through Debt.

Component 2 includes financial performance. Liquidity (0.834) and economic margin (0.686) define a group of municipalities with good operating performance and, therefore, those that can cover their obligations from their own operating activities. Debt service shows a negative value (-0.470), which is consistent with economic logic: the more a municipality pays in instalments, the less it has left for operations. Component 3 represents debt and social burden. The unemployment rate (0.898) and debt service (0.733) form a combination capturing financial vulnerability conditioned by the socio-economic environment. Municipalities with higher unemployment have a lower tax base, which increases the relative burden of instalments, not only because of the amount of Debt but also because of a weaker revenue position. This mechanism, as described by OECD (2024), is one of the main channels through which social risks are transmitted to local governments' financial results. NO₂ was separated into a distinct component (0.955), confirming that its source structure differs from that of the PM fractions. NO₂ primarily originates from road transport, not from heating or industry, and different local factors govern its distribution in the sample. Including NO₂ in the same index as PM without further consideration would therefore lead to methodological bias.

Table 3: Rotated Component Matrix

	Component				Communalities
	1	2	3	4	Extraction
Indebtedness	0.714	0.394	0.143	0.234	0.74
Cash	-0.072	0.834	-0.233	-0.039	0.755
Margin	-0.417	0.686	-0.148	0.232	0.721
Debt Servis	0.03	-0.47	0.733	0.024	0.759
Unemployment	0.09	-0.046	0.898	-0.183	0.85
PM10	0.846	-0.299	0.065	0.253	0.874
PM2.5	0.833	-0.388	-0.013	-0.109	0.856
NO ₂	0.166	0.065	-0.152	0.955	0.966

Source: own

The last column reports the communalities, or the shares of variance of each variable explained by the four components together. All values exceed 0.72, confirming that the model captures each input variable well and that none are marginalised. The highest communality belongs to NO₂ (0.966), a consequence of its almost exclusive binding to the fourth component. The lowest communality of the economic margin (0.721) is still sufficient and does not require any model correction.

The Discriminant analysis used the dependent variable Debt - municipalities without problem (No, $n = 29$) and municipalities with problematic Debt (Yes, $n = 5$) and eight predictive variables. The canonical correlation of 0.520 corresponds to a moderately strong association between the discriminant function and group assignment. A Wilks' Lambda of 0.729 means that 72.9% of the variability in the discriminant score is not due to group affiliation. The chi-square test ($\chi^2 = 8.843$, $df = 8$) yields $p = 0.356$. The model is not statistically significant. With five cases in the smaller group and eight predictor variables, the ratio is 8:5, which exceeds the recommended rate by a significant margin (Piermarini et al., 2023). The model should be seen as an orienting tool for identifying patterns, rather than as statistically strong evidence.

Table 4: Standardised Canonical Discriminant Function Coefficient and

Standardized Canonical Discriminant Function Coefficient		Structure matrix	
Indebtedness	0.377	PM2.5	0.492
Cash	-0.484	NO2	-0.445
Margin	0.902	Unemployment	0.370
Debt Servis	0.281	Cash	-0.280
Unemployment	0.078	PM10	0.151
PM10	-1.083	Debt Servis	0.142
PM2.5	1.625	Margin	-0.052
NO2	-0.447	Indebtedness	0.022

Source: own

The main variable, according to the standardised coefficients, is the economic margin (0.902), and a higher operating surplus is associated with belonging to the problem-free group. Liquidity follows (-0.484) with a negative coefficient, which at first glance appears negative. A possible explanation is that municipalities close to insolvency deliberately maintain higher cash reserves as a line of defence, or that the effect arises from mutual correlation between the variables. The third in order is debt service (0.281). The structure matrix shows a different ordering than the standardised coefficients. The strongest direct correlations with the discriminant function are shown by PM2.5 (+0.492), NO2 (-0.445), and the unemployment rate (+0.370). The economic margin, dominant according to the coefficients, drops to seventh place (-0.052). The conclusion is methodologically important because the ES factors carry real discriminant information, but stronger financial predictor

variables partially obscure it. Based on the unstandardized coefficients, the discriminant function can be written:

$$Z = 14.708 \text{Margin} - 8.792 \text{Cash} + 6.067 \text{Debt Service} - 0.234 \text{PM10} + 0.531 \text{PM2.5} - 0.068 \text{NO2} - 1.738$$

Municipalities with a Z value above the dividing point are included in the debt-free group, and municipalities with a lower value in the risk group. The centroids confirm the direction: problem-free villages have an average function value of +0.245, while risky villages have a value of -1.424. We used a cross-tabulation to compare the actual and model-predicted classifications of municipalities in the original data and in leave-one-out cross-validation. On the original data, the model correctly classifies 82.4% of cases. Of the 29 problem-free municipalities, 24 (82.8%) were correctly classified, and of the 5 risky municipalities, 4 (80.0%) were correctly identified. Cross-validation reduces overall accuracy to 70.6%, and among the 5 risky municipalities, the model correctly identified only 3. The 12 percentage-point decrease reflects the model's adaptation to the data, an expected phenomenon in a smaller group with $n = 5$.

From the point of view of practical use, the more serious type I error is the classification of a risky municipality among the problem-free ones. In this way, 2 out of 5 risky municipalities (i.e., 40%) are overlooked in the cross-validation. For an early warning system, such a proportion would be unacceptable, and the classification threshold would need to be set in favour of sensitivity. To improve the model, we recommend increasing the sample size.

6 Conclusion

Factor analysis showed that financial variables are divided into two latent dimensions: the first, liquidity and economic margin (component 2); the second, debt service in combination with unemployment (component 3). Together, these two dimensions account for 40.7% of the variability in the set. Interestingly, indebtedness is grouped with environmental variables, indicating its link to external shocks rather than to systemic management errors. This finding aligns with the INEKO diagnostic framework (2024), which identifies liquidity, current account balance, and debt service as key signal variables for municipalities' financial health. In total, the analysis extracted four components, which explained 81.5% of the variability. Component 1 links the environmental burdens of PM10 and PM2.5 to

indebtedness; component 2 captures financial performance; component 3 captures debt and social burden; and component 4 captures isolated NO₂ concentrations. The very combination of environmental and financial variables within a single component empirically supports the thesis that environmental risks are transferred to municipalities' financial condition, as formulated by OECD (2024) and Cappiello et al. (2025).

The discriminant analysis confirmed that the decisive factor between the groups is the economic margin, followed by liquidity and debt service. The result aligns with Lukáč et al. (2021) and the regulatory logic of the RRZ (2025), which bases the rules of financial responsibility on revenue capacity and liabilities. The model achieves 82.4% accuracy on the original data and 70.6% in cross-validation. However, the difference is not statistically significant ($p = 0.356$), due to the critically small number of risky municipalities in the sample ($n = 5$). The results should be seen as indicative. The structural matrix also revealed that PM_{2.5} and NO₂ have a stronger direct correlation with the discriminant function than most financial variables, and their discriminant potential is therefore real, only partially overshadowed by stronger financial variables. Bruno and Henisz (2024) document that ESG characteristics of the territory are associated with lower credit risk, and their results suggest this direction, although a larger, more representative sample would be necessary for definitive confirmation. Our work contributes to the discussion on the inclusion of the ESG perspective in the assessment of the financial health of Slovak local governments. It shows that environmental and social factors represent a meaningful complement to traditional financial analysis.

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CONSUMER TRUST IN THE ARTIFICIAL INTELLIGENCE ERA: INFLUENCE OF DATA PROTECTION PRACTICES ON PURCHASE INTENTION

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This paper examines how data protection practices function as early indicators of trust and governance mechanisms in AI-driven, data-intensive digital markets. Within the digital economy, data-driven value creation through personalization, segmentation, and relationship management amplifies privacy and risk concerns, which subsequently influence the evolution of trust. Effective data protection and transparent communication are identified as critical determinants of market value. While structural cues are initially prominent, the website experience gains importance as user interactions progress. The expansion of data processing and sharing in AI environments further highlights the necessity of maintaining privacy balances. This article clarifies the essential role of open and standardized privacy communication in fostering consumer trust and enhancing market value, and discusses implications for marketing, policy, and future research. This study integrates previously fragmented discussions on privacy assurance, personal data control, transparency, perceived risk, and purchase intention into a concise conceptual framework. This framework explains how data protection practices function as trust-building mechanisms in AI-driven digital markets.

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1 Introduction

Within the digital economy, organizations generate value through personalization, segmentation, and relationship management, all of which depend on customer data. Although data-driven value creation offers advantages to consumers, it also increases perceptions of uncertainty and risk, thereby emphasizing the critical role of trust. Trust in online environments is dynamic and develops throughout the decision-making process. As this process unfolds, the cues influencing trust formation may change. Research demonstrates that structural trust indicators are most influential during the initial stages of decision making, whereas factors related to the website experience become more prominent as user interaction continues (McKnight et al., 2004). In this context, data protection practices function as early indicators of trust that inform consumers' trust assessments. The effectiveness of these practices, however, is contingent upon both the specific context and the manner in which they are communicated during the decision-making process.

In the age of artificial intelligence, the increasing data processing capacity is raising uncertainties regarding the collection, processing, and sharing of consumer data. This development necessitates balancing benefits with privacy concerns in consumer interactions with data-driven services. Consumers need clear, comparable information to assess data protection assurances effectively. Research on the privacy label approach developed under the General Data Protection Regulation (GDPR) reveals that current practices often fail to improve consumers' perceptions of privacy and control. Conversely, more transparent and standardized information presentations can increase perceived levels of control, privacy, and trust (Fox et al., 2022). Therefore, the fundamental challenge in the context of artificial intelligence is to go beyond data processing and ensure that these processes are understandable, traceable, and manageable from a consumer perspective.

Data protection practices foster trust in marketing and indicate responsible data management. However, trust is influenced not only by these practices but also by consumers' awareness and comprehension of them during decision-making. When privacy information is made available, research demonstrates that consumers prefer options with stronger privacy protection and are willing to pay a premium for such options (Tsai et al., 2011). While data protection entails compliance costs, it also generates market value. The effectiveness of trust signals varies; certain third-party

signals do not enhance consumer trust (McKnight et al., 2004). Therefore, data protection communication should employ clear and easily understandable signals for consumers. This paper contributes to the literature by conceptualizing data protection practices as both regulatory requirements and early-stage trust signals in AI-driven consumer markets. It integrates privacy assurance, perceived control, transparency, perceived risk, and purchase intention into a unified conceptual framework. This discussion-oriented framework is intended to inform future empirical research on consumer evaluation of data protection practices during purchasing decisions in data-intensive digital environments.

2 Literature review

2.1 Consumer Trust in AI-Driven Digital Environments

Trust is widely recognized as a critical determinant in digital environments, especially within e-commerce, due to the virtual nature of transactions and the absence of direct interpersonal interaction. According to Habib and Hamadneh (2021), trust holds greater significance in online shopping than in traditional transactions and serves as a fundamental factor in the adoption of new technologies and the expansion of e-commerce. The same study further demonstrates that trust is positively correlated with technical security features, ease of site navigation, information presentation, and verification.

Within this framework, consumer trust functions as a mechanism closely linked to perceived risk and uncertainty. Habib and Hamadneh (2021) assert that consumers often perceive online shopping as risky, with "fear of the unknown" identified as a primary barrier to online purchasing. The same study suggests that perceived risk is assessed in relation to the "subjective ambiguity" of potential outcomes. Similarly, Hipólito et al. (2025) find that consumer trust in online shopping environments reduces perceived risk and consequently enhances satisfaction with the shopping experience. Their research also observes that businesses implement return policies to mitigate consumer uncertainty. However, the effect of a free return option on risk perception and satisfaction may be less substantial than anticipated, while an open return policy can lead to increased satisfaction. Additionally, a non-linear relationship is proposed between risk perception and satisfaction, indicating that satisfaction may peak at an optimal level of risk, forming an inverse U-shaped

relationship. In digital contexts, trust is evaluated not only in terms of confidence in technology or online systems but also through trust beliefs related to firms' data collection practices. Addressing the personalization-privacy paradox, Cloarec et al. (2024) emphasize the tension between the desire for personalized experiences and the need to protect personal data, defining trust beliefs and concerns about information collection as central components of their models.

2.2 Data Protection Practices as Responsible Data Governance

Fox et al. (2022) demonstrate that GDPR-style visual privacy labels are more effective than lengthy, text-based privacy policies in shaping consumers' privacy perceptions and behaviors within e-commerce. These labels reduce perceived risks and enhance feelings of control, particularly when explicit consent mechanisms are implemented. Increased control and privacy strengthen consumers' perceptions of company trustworthiness, encompassing benevolence, honesty, and competence. This, in turn, elevates purchase intent and willingness to provide accurate data. The authors contend that responsible data management should extend beyond compliance, advocating for transparency and actionable practices that empower user control and foster trust in cross-border regulatory environments.

Zimmermann et al. (2024) conceptualize personal data control as a multi-stage construct comprising four distinct activities in consumer-firm data exchanges: collection, transmission, access, and use. Their findings indicate that consumers can distinguish among these stages, although subjective perceptions of control do not always align with objective behavioral control. When multiple activities occur simultaneously or when active participation is limited, perceptions of collection and transmission may overlap, and some perceptions of data flow may converge. The authors recommend that both research and practice employ comprehensive measurement approaches encompassing all four control activities, as reliance on single-factor measures may distort consumer evaluations in data disclosure contexts. By distinguishing between active, passive, and hybrid disclosure scenarios, the study broadens the discourse on privacy and technology adoption. The authors further assert that control over data inputs in automated and artificial intelligence contexts is a critical management issue rather than solely a technical concern.

Thompson and Siamagka (2022) report that perceptions of ethical care in organizational privacy practices positively influence both perceived information control and trust in the company. These perceptions subsequently shape consumers' information-sharing behaviors. The accuracy of information shared is fully determined by perceived information control and trust, while the quantity of information shared is primarily affected by the direct influence of perceived ethical care. Using structural equation modeling and experimental methods, the authors' model accounts for 18.1% of the variance in the amount of information shared and 37.6% of the variance in willingness to share accurate information, outperforming a regulation-based antecedent model in both fit and explanatory power. The authors conclude that adopting an ethical care governance perspective, rather than relying exclusively on regulations, may mitigate privacy-related issues such as data withholding or falsification and promote more accurate data disclosure by enhancing perceptions of control and trust linked to transparency.

Montecchi et al. (2024) find that perceived brand transparency, conceptualized as a second-order construct, demonstrates strong model fit and discriminant validity within their proposed framework. Structural equation modeling results indicate that perceived brand transparency is strongly and positively associated with key managerial outcomes, including brand credibility, integrity, authenticity, beliefs about corporate social responsibility and ethics, and brand trust. The authors also observe that higher perceived brand transparency correlates with more favorable purchase intentions. The study concludes that transparency strategies can reduce information asymmetry and consumer skepticism, rebuild trust, and foster mutually beneficial, trust-based relationships between brands and consumers.

2.3 Trust and Data-Driven Behavior in AI Environments

The widespread adoption of the internet in Business-to-Consumer commerce has intensified academic focus on firm-customer interactions in online settings. In this context, trust is a fundamental driver of consumer engagement. Elevated trust in e-commerce, alongside substantial web experience, increases the probability of consumers participating in online shopping. Key determinants of trust include perceived market orientation, site quality, technical reliability, and users' web experience. High perceived site quality is particularly associated with stronger market

orientation and reliability. Enhanced trust, in turn, promotes greater engagement in e-commerce (Corbitt et al., 2003).

A trust-based consumer decision model has been introduced to analyze the interplay between trust and risk in online purchasing. According to this model, trust, perceived risk, and perceived benefit each exert direct effects on purchase intentions and decisions. Trust also indirectly influences purchase intention by mitigating perceived risk. Empirical evidence indicates that trust has a strong positive impact on purchase intention, whereas perceived risk reduces it and perceived benefit increases it. These factors also shape actual purchasing behavior. Consumers' perceptions of privacy and security significantly influence both trust and risk, indicating that privacy and security are assessed as distinct constructs in online shopping. While familiarity substantially affects purchase intention and trust, it does not significantly alter perceived risk. Conversely, a predisposition to trust has a notable effect on consumer trust (Kim et al., 2008).

In the context of the attention economy, achieving an effective balance between personalized advertising and consumer privacy remains a considerable challenge. The allocation of consumer attention is a crucial variable in this dynamic. Limitations on attention can hinder online social interactions and restrict consumers' ability to effectively manage their privacy (Cloarec, 2020). The growing implementation of data-driven technologies and algorithms has increased the collection of personal data across digital and physical environments, thereby enhancing companies' ability to monitor and track media users. As a result, perceived surveillance has become a prominent subject in data-driven communication research. The experience of being observed is associated with decreased media usage and may lead to shifts in media consumption behaviors (Segijn et al., 2022; McDonald & Cranor, 2010). To address the lack of a robust measurement tool, Segijn et al. (2022) validated the Perceived Surveillance Scale across multiple datasets, confirming its reliability for assessing perceived surveillance arising from personalization techniques and personalized communication. Findings on construct validity reveal that perceived surveillance is positively correlated with privacy concerns, perceived privacy risk, perceived vulnerability and seriousness, intimidation, surveillance anxieties, and perceived personalization, and negatively correlated with attitudes toward personalization. Unexpectedly, a positive relationship was found between trust in the fair use of personal data and perceived surveillance, which may serve as a coping response to

privacy concerns (Segijn et al., 2022; Hoffmann et al., 2016; Lutz et al., 2020; van Ooijen et al., 2022).

Prior research demonstrates that trust, perceived risk, privacy assurance, transparency, and personal data control are significant determinants of consumer behavior in online environments. However, the literature is fragmented, with some studies emphasizing trust and perceived risk, while others examine privacy labels, transparency, ethical data practices, or perceived surveillance. For example, Fox et al. (2022) report that GDPR-style privacy labels influence consumers' privacy perceptions, perceived control, trust, and behavioral intentions. Zimmermann et al. (2024) propose that personal data control should be understood as a multi-stage construct within technology-mediated contexts. Montecchi et al. (2024) show that perceived brand transparency is associated with favorable brand evaluations, including trust-related outcomes and purchase intentions. Despite these findings, the role of data protection practices as an integrated trust-building mechanism in AI-driven markets remains insufficiently defined.

Another limitation in the literature is the predominant focus on data protection from either a regulatory compliance or consumer privacy perspective. Few studies examine its strategic function as a market signal that can shape perceived trustworthiness and purchase intention. Mattison Thompson and Siamagka (2022) support this perspective by demonstrating that organizational privacy ethical care enhances perceived information control and trust. This research gap is especially relevant in AI-driven environments, where data collection, algorithmic personalization, and automated decision-making increase both the benefits and perceived risks of digital interaction, thereby intensifying the personalization–privacy paradox (Cloarec et al., 2024). Therefore, data protection practices should be conceptualized as governance-based trust cues. When these practices are communicated in a transparent, standardized, and consumer-oriented manner, they can reduce perceived uncertainty, enhance perceived control, and support purchase intention.

3 Methodology

This article contends that data protection practices are essential indicators of trust and function as governance mechanisms within AI-driven digital environments. Adopting an interdisciplinary perspective, it integrates insights from marketing, information systems, digital consumer behavior, and responsible data governance to examine the operation of these mechanisms. The analysis centers on key concepts such as online trust, perceived risk, purchase intention, privacy assurance, personal data control, ethical diligence, brand transparency, the personalization-privacy paradox, and perceived surveillance. Relevant keywords include consumer trust, data protection, GDPR, personal data control, ethical diligence, brand transparency, purchase intention, perceived risk, personalization-privacy paradox, AI-powered marketing, data-driven communication, and surveillance.

This study employs a conceptual and literature-based methodology, aiming to synthesize existing theoretical and empirical findings into a coherent conceptual framework instead of testing causal relationships with primary data. The analysis draws upon prior research in marketing, information systems, consumer behavior, privacy studies, and responsible data governance. These studies facilitate the identification of recurring constructs, relationships, and research gaps concerning data protection, trust formation, perceived risk, perceived control, transparency, and purchase intention. Drawing upon existing literature, this study introduces a conceptual framework that illustrates the role of data protection in fostering trust within digital environments. The article emphasizes the necessity for robust conceptual models, reliable measurement instruments, and empirical evidence to substantiate the relationship among trust, privacy, and consumer behavior. Although primary quantitative data are not presented in this paper, a foundation is established for future empirical validation. The proposed framework can be evaluated through survey-based research, experimental designs, or structural equation modeling. Future studies could examine whether transparent privacy communication enhances perceived control and trust, whether perceived risk mediates the relationship between data protection and purchase intention, and whether AI-driven personalization increases privacy concerns or perceived surveillance.

Proposed Directions for Future Empirical Research

Drawing from the proposed framework, future empirical studies can empirically test the following propositions:

P1. Transparent communication regarding data protection enhances perceived consumer control.

P2. Higher levels of perceived consumer control strengthen consumer trust.

P3. Increased perceived risk diminishes purchase intention.

P4. Greater consumer trust leads to higher purchase intention.

P5. Perceived risk serves as a mediator between data protection practices and purchase intention.

P6. Perceived surveillance can undermine consumer trust when data protection practices lack clarity.

4 Results and Discussion

The literature shows that data protection practices shape consumer purchase intentions through several interconnected mechanisms. Transparent privacy communication and responsible data governance increase perceived control and build consumer trust, while also reducing perceived risk and uncertainty. In AI-driven contexts, personalization and perceived surveillance may intensify privacy concerns, eroding trust if data protection practices are not communicated effectively. Figure 1 demonstrates how these mechanisms are conceptually linked within AI-driven digital markets.

The literature demonstrates that in AI-driven, data-intensive digital markets, data protection practices function as early indicators of trust, enabling consumers to manage uncertainty and perceived risk in online decision-making. Trust assumes a dynamic role throughout this process. Although structural indicators are initially

prominent, the quality of website experience becomes increasingly decisive as user interaction grows (McKnight et al., 2004). The effectiveness of data protection practices is determined not only by their presence but also by the clarity of their communication and the extent of consumer understanding.

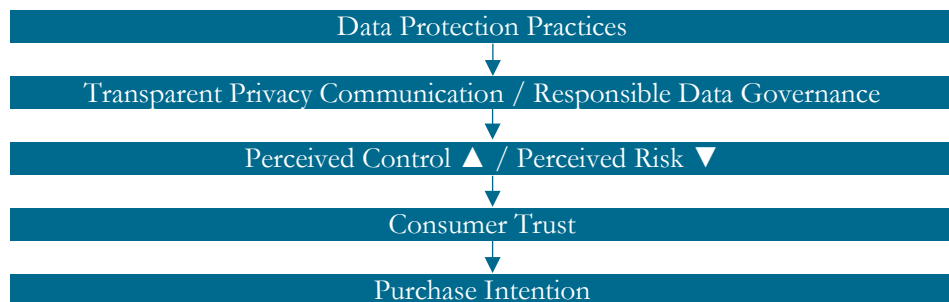


Figure 1: Conceptual Framework of Data Protection, Trust, and Purchase Intention

A critical reading of the literature indicates that the relationship between data protection and trust is not inherently direct. The presence of privacy policies, assurance seals, or formal compliance mechanisms alone may not be sufficient to enhance consumer trust. More significant is the extent to which consumers can understand, compare, and evaluate these practices during their decision-making. This distinction is crucial because certain trust signals may prove ineffective if they are overly complex, merely formally standardized, or disconnected from consumers' actual experiences. Consequently, the effectiveness of data protection relies not only on institutional compliance but also on communicative clarity and the perceived usefulness to consumers.

Within AI environments, increased data processing capacity amplifies uncertainty regarding the collection, processing, and sharing of data. This underscores the necessity of balancing data-driven advantages with privacy concerns. Consumers increasingly require clear and comparable information about data protection assurances. Evidence regarding GDPR-like privacy labels suggests that current practices frequently fail to enhance perceptions of privacy and control. More transparent and standardized presentations may improve perceived control, privacy, and trust (Fox et al., 2022). When privacy information is available, consumers are more likely to prefer and pay for alternatives offering stronger protection. This

outcome indicates that data protection can generate market value despite associated costs (Tsai et al., 2011).

Research indicates that AI-driven data applications contribute to increased uncertainty. Data protection and effective communication emerge as essential governance mechanisms that influence perceived control, privacy, and trust (McKnight et al., 2004; Fox et al., 2022). Trust, in particular, facilitates consumer interaction with digital platforms and correlates with purchasing behavior in social commerce contexts (Wang & Herrando, 2019). Consequently, data protection should be considered not only as a matter of legal compliance but also as an integral component of responsible data management and sustainable governance frameworks. Establishing trust is therefore fundamental to fostering market engagement and generating value.

The literature identifies several areas requiring further empirical investigation. Researchers are encouraged to examine the impact of trust cues at each stage of the decision-making process. It is also necessary to assess whether transparent and standardized privacy communications, such as GDPR-style labeling, enhance perceptions of control, privacy, and trust. Researchers should evaluate how privacy information influences consumer preferences and willingness to pay. Findings suggest that marketers should provide clear, comparable, and comprehensible privacy assurances. Since not all trust signals are equally effective, policymakers are advised to promote disclosures that render data practices transparent, traceable, and manageable for consumers.

5 Conclusion

This study demonstrates that in AI-driven, data-intensive digital markets, data protection practices foster trust by reducing uncertainty and risk in consumers' online decision-making. The effectiveness of data protection depends not only on its implementation but also on the clarity and comprehensibility of its communication. Extensive data processing, collection, and sharing in AI contexts present significant concerns. Transparent and standardized privacy information is essential for enhancing perceived control, privacy, and trust. Effective data protection requires both regulatory compliance and responsible data management, as well as sustainable governance to promote consumer engagement and value

creation. Future research should investigate the influence of trust cues on decision-making and assess how privacy communication affects consumer preferences and willingness to pay. Policy initiatives should emphasize consumer-oriented, clear, and comparable privacy assurances.

The present study is limited by its conceptual and literature-based approach. Therefore, empirical validation of the proposed relationships is required in subsequent research. Future quantitative studies should examine the effects of privacy assurance, perceived control, perceived risk, and consumer trust on purchase intention. Furthermore, experimental research may compare different forms of privacy communication, such as traditional privacy policies, visual privacy labels, and AI-specific transparency notices. Such investigations would help determine which data protection signals most effectively enhance consumer trust in AI-driven markets.

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DIGITAL STUDENT IDENTITY SYSTEMS AND SUSTAINABLE GOVERNANCE IN HIGHER EDUCATION: AN EMPIRICAL STUDY USING THE TECHNOLOGY ACCEPTANCE MODEL

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Digital identity systems are becoming an important component of higher education institutions' digital transformation, enabling more efficient administrative processes and improved access to campus services. This study examines students' acceptance of digital student identification cards using the Technology Acceptance Model (TAM). An extended TAM framework incorporating trust in system security was applied to analyse the relationships between perceived usefulness, perceived ease of use, attitude toward use, behavioural intention, and trust. Empirical data were collected through a survey of students enrolled at three Slovenian universities. Factor analysis revealed that perceived usefulness consists of two dimensions: administrative functions and student services. Regression analysis showed that perceived ease of use and the perceived usefulness of administrative functions significantly influence students' attitudes toward digital student identification cards. Trust in system security also positively affects the perceived usefulness of administrative functions. The study contributes to understanding the role of digital identity systems within the digital transformation of higher education institutions.

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1 Introduction

Digital transformation has become a central driver of change in contemporary organisations and institutions. These developments are increasingly linked with broader sustainability objectives, particularly within the framework of environmental, social, and governance (ESG) principles. Organisations are therefore expected not only to adopt digital technologies but also to ensure that digital innovation contributes to more sustainable, efficient, and transparent organisational processes (Vial, 2019).

Higher education institutions are no exception to these developments. Universities are increasingly integrating digital technologies into administrative, educational, and service processes to improve institutional efficiency and enhance the student experience. Digital transformation in higher education is increasingly viewed as an important mechanism for supporting sustainable institutional governance. Digital solutions may contribute to environmental sustainability by reducing consumption of physical resources, while simultaneously supporting social inclusion through improved service accessibility and strengthening governance transparency through more reliable, traceable digital processes.

Within this broader context, digital student identity systems represent an important component of modern universities' digital infrastructure. Among these solutions, digital student identification cards have emerged as a key tool for secure identification, access management, and the integration of various student services within the digital campus environment. In contrast to traditional physical student identification cards, digital solutions offer greater flexibility, integration with mobile devices, and the ability to update student information dynamically. At the same time, digital credentials may enable more efficient service delivery and reduce the administrative burden of issuing and managing physical cards. Furthermore, they reduce material consumption and plastic waste while enabling more transparent, traceable, and accountable institutional processes, thereby supporting the broader sustainability objectives of higher education institutions.

The development of digital student identification systems is also closely linked to broader European initiatives to advance the digital transformation of higher education. One of the most important initiatives in this context is the European

Student Card Initiative, which aims to simplify administrative procedures for student mobility and enable more efficient digital student identification across European higher education institutions (European Commission, 2024a). By integrating digital identification infrastructures, these initiatives contribute to creating a more interconnected and digitally supported European higher education ecosystem.

Despite the technological maturity and potential benefits of digital student identification cards, their successful implementation depends not only on technological capabilities but also on user acceptance. The adoption and effective use of digital systems largely depend on users' willingness to accept and actively use the technology. Even technologically advanced systems may face limited adoption if users perceive them as difficult to use, insufficiently useful, or potentially insecure.

Understanding the determinants of technology acceptance has therefore become an important area of research in information systems. One of the most widely applied theoretical frameworks for explaining user acceptance of information technology is the Technology Acceptance Model (TAM), which proposes that users' behavioural intentions to adopt a technology are primarily influenced by their perceptions of the system's usefulness and ease of use (Davis, 1989). Subsequent research has extended the model by incorporating additional factors that may influence technology adoption, such as trust in system security or institutional context (Venkatesh & Davis, 2000).

However, a limitation of existing TAM literature is its predominant focus on voluntary usage contexts, such as e-mail or basic office software (Sternad Zabukovšek & Samo, 2023). In such settings, users have the discretion to reject a technology they find difficult or unhelpful. In contrast, digital student identification cards often represent a mandatory technological shift within university digital infrastructures. Academic research suggests that in mandatory environments, the traditional dynamics of technology acceptance are significantly altered. For instance, while perceived ease of use (PEOU) is a hallmark of voluntary adoption, it may become statistically non-significant in mandatory settings, as users are required to utilise the system to perform essential tasks regardless of its perceived complexity (Sternad Zabukovšek & Samo, 2023).

Despite the fact that TAM has been widely applied in studies examining the adoption of various digital technologies, empirical research on students' acceptance of mandatory digital identification cards in higher education remains limited. In particular, there is a lack of empirical studies examining how students perceive the usefulness, usability, and security of digital student identification systems within university digital infrastructures where usage is not optional. This represents an important research gap, especially considering the growing role of digital identity systems in university governance and digital campus environments. This study addresses this gap by examining students' acceptance within a mandatory institutional framework, thereby providing academic added value beyond a standard context-application of TAM. It investigates how traditional acceptance constructs behave when technology becomes a prerequisite for participation in the university ecosystem, specifically testing if factors like perceived ease of use remain significant when users have no discretion to reject the system.

Building on this research gap, this study aims to examine the factors influencing students' acceptance of digital student identification cards using selected TAM constructs. In particular, the study investigates how perceived usefulness and perceived ease of use influence students' attitudes toward the use of digital student identification cards and their behavioural intention to use them. In addition, the study incorporates trust in the security of the digital student identification card as an additional factor that may influence students' perceptions of the system.

The empirical analysis is based on survey data collected from students at Slovenian universities (Hajdenkumer, 2025). By examining the determinants of students' acceptance of digital student identification cards, the study contributes to a better understanding of how digital identity systems may support the digital transformation and sustainable governance of higher education institutions.

The remainder of the paper is structured as follows. The next section presents the theoretical background and literature review on digital student identity systems and the Technology Acceptance Model. The description of the research methodology and empirical analysis follows this. The subsequent section discusses the study's results, and the final section presents the main conclusions, limitations, and directions for future research.

2 Theoretical background

2.1 Student identification systems in higher education

Student identification systems are an essential component of the administrative and service infrastructure within higher education institutions. Universities rely on identification systems to verify students' identities and academic status, and to enable secure access to various institutional services and facilities. These systems support the efficient management of student records, access rights, and service provision within increasingly digitalised campus environments.

Traditionally, student identification systems have been implemented through physical student identification cards that function as official institutional credentials (University of Maribor, 2013). Over time, these systems have evolved from simple identification tools into multifunctional platforms that support a wide range of academic, administrative, and service-related functions. As higher education institutions continue to integrate digital technologies into their operations, student identification systems are becoming increasingly important components of modern universities' broader digital infrastructure.

Student identification cards primarily serve as official credentials that confirm a student's identity and enrollment status within a higher education institution (University of Maribor, 2013). In their basic form, such cards contain key personal and institutional information, including the student's name, student identification number, photograph, and the issuing university's name (Ludwig-Maximilians-Universität München, 2025), as shown in Figure 1.

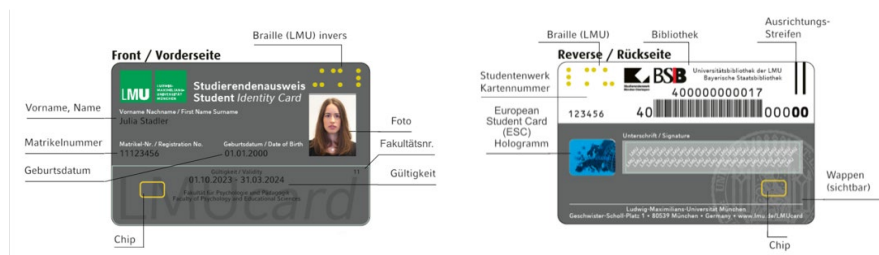


Figure 1: Student identification card of the Ludwig-Maximilians-Universität München

Source: (Ludwig-Maximilians-Universität München, 2025).

In addition to their identification function, student identification cards are widely used to enable access to various university services and facilities. These may include entry to lecture halls, laboratories, libraries, and other campus buildings (Maribor University Library, 2025). Student identification cards may also be used for administrative and service purposes, such as borrowing library materials, accessing study rooms, recording attendance, or verifying eligibility for student benefits, as shown in Figure 2.



Figure 2: Student identification card of the University of Maribor

Source: (University of Maribor, 2013).

Many universities also integrate additional functionalities into their identification systems, enabling student cards to serve as authentication tools within institutional information systems. For example, student identification cards may be used for subsidised student meal systems, cashless payments in campus cafeterias, printing and copying services, or access to public transportation schemes associated with student mobility programs (Bajić & Orel, 2025). Due to these diverse functionalities, student identification cards represent an important operational element of the administrative and service infrastructure of higher education institutions.

As universities increasingly adopt integrated digital infrastructures, student identification systems are becoming part of broader digital campus ecosystems that connect physical access control, administrative systems, and digital services into a unified identification environment. In such environments, a single student credential can enable access to multiple institutional services, thereby improving service delivery efficiency and supporting more coordinated management of campus processes.

From a technological perspective, student identification systems have evolved significantly over time, reflecting broader developments in identification technologies and digital campus infrastructures. Early versions of student identification cards were primarily designed as simple visual identification documents containing basic personal information and photographs. Verification was therefore limited to manual inspection, and such cards did not support integration with digital systems (Loechel, Alves, & Persson, 2022).

Subsequent technological developments introduced cards with machine-readable elements, such as barcodes or QR codes. These technologies enable automated identification through optical scanning and allow the integration of identification cards with certain institutional services. Although such solutions represent a technological improvement compared with purely visual identification cards, their interoperability and functional flexibility remain limited.

More advanced solutions include identification cards equipped with embedded chips that enable electronic authentication through specialised card readers. Chip-based cards support a broader range of services, including access control systems, electronic payments, and integration with institutional databases. These cards represent an intermediate step toward the development of multifunctional campus identification systems (Loechel, Alves, & Persson, 2022)

The most technologically advanced physical solutions are smart cards that incorporate multifunctional chips capable of supporting multiple authentication methods, including contact and contactless communication technologies. Smart cards enable greater interoperability and allow universities to expand services associated with student identification cards dynamically. Such solutions have become a central component of modern digital campus infrastructures.

Recent developments have further expanded these systems by introducing virtual or mobile identification solutions implemented through smartphones. Mobile-based identification systems eliminate the need for physical card production and instead rely on digital credentials stored on mobile devices. These systems may integrate multiple authentication mechanisms, including QR codes, near-field communication (NFC), and biometric verification, thereby enabling flexible and secure identification within digital campus environments (Loechel, Alves, & Persson, 2022).

The transition from traditional physical cards to digital identification solutions reflects a broader trend toward the digitalisation of administrative processes and services within higher education institutions. As universities increasingly adopt integrated digital infrastructures, student identification systems are evolving from simple identification documents into multifunctional digital credentials that support a wide range of academic and administrative services.

2.2 Digital student identification cards

Digital student identification cards represent the digital evolution of traditional student identification systems used within higher education institutions. While physical student identification cards have long served as official credentials confirming student identity and status, digital student identification cards extend these functions into the digital environment by enabling electronic identification, authentication, and integration with various digital services.

A digital student identification card is a digital credential containing verified information about a student and issued by a higher education institution. Such credentials typically store key identification attributes, including the student's name, photograph, institutional affiliation, and student identification number. In addition to basic personal data, a digital card may also contain other types of information, such as health-related data, academic history, and similar records (Zahlimar, Bakar, Permana, Siswoyo, & Hamirul, 2023). In contrast to physical cards, digital credentials are typically stored and accessed on mobile devices in digital wallets, enabling students to present their identification electronically when accessing institutional services.

Digital student identification cards are often integrated into broader university information systems and digital campus infrastructures. Through such integration, they enable students to authenticate their identity when accessing campus facilities, borrowing library materials, or using university services. In addition, digital credentials may support various authentication mechanisms, such as QR-code verification, near-field communication (NFC), or biometric authentication on mobile devices, thereby enhancing both usability and security.

In many cases, digital student identification cards function as part of a broader digital identity ecosystem that connects institutional databases, access management systems, and service platforms. Within such ecosystems, digital credentials enable universities to manage student identities more efficiently while simultaneously simplifying student access to services.

Although the adoption of digital identification systems varies across countries and institutions, many higher education systems have begun introducing regulatory frameworks to support the transition from physical to digital student credentials. For example, in Slovenia, the Act Regulating the Status of Students allows higher education institutions to issue student identification cards in digital form, thereby formally enabling the development of mobile-based student identification solutions (ZUPŠ-1, 2022). Similar developments can also be observed in other higher education systems that are gradually introducing digital credentials as part of broader digital transformation strategies (Bajić & Orel, 2025). Figure 3 presents the Croatian national digital student identification card.

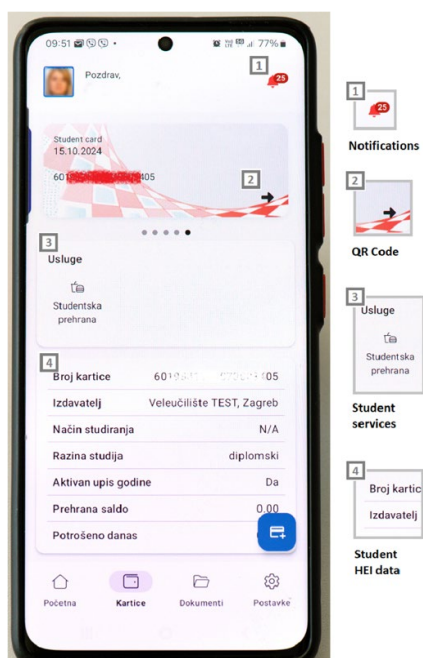


Figure 2: Digital student identification card of Croatia

Source: (Bajić & Orel, 2025)

The growing adoption of digital student identification cards reflects broader developments in digital identity management and the increasing importance of secure digital credentials within higher education environments.

Digital identification cards not only address key limitations of physical cards, such as inconvenience, the cost of reprinting, and susceptibility to wear, but also provide multiple benefits ranging from operational cost savings to improvements in the student experience. The most important advantages are outlined below.

The issuance and management of digital identification cards can be centralised and completed within minutes. Administrators can update or revoke access rights in real time through a web interface, without requiring students to physically visit the card office (ScreenCheck Europe B.V., 2025). As a result, the issuance process can be reduced from several days to a matter of seconds, significantly reducing the administrative workload.

Digital solutions also eliminate costs associated with plastic materials, printing, card personalisation printers, and distribution logistics. Each card that is not made from polyvinyl chloride (PVC) reduces plastic waste and lowers the supply chain's carbon footprint. Higher education institutions that have adopted mobile identification cards report measurable reductions in plastic use and emissions associated with card distribution (Emerald Expositions, 2025).

Darmawan and Santoso (2018) similarly highlighted that printing large quantities of physical cards is environmentally unsustainable, although they note that biodegradable materials could represent a partial solution to this issue.

Digital identification cards also employ advanced security mechanisms, such as encryption, biometric authentication, and multi-factor authentication, which reduce the risk of counterfeiting and unauthorised access (Emerald Expositions, 2025). In addition, if a mobile device is lost, the digital card can be immediately deactivated, significantly reducing the risk of misuse, a common problem associated with physical cards.

Whereas changes to personal information, such as address or academic status, require the reprinting of a physical card, digital identification cards can automatically update stored information as soon as changes are made within the university information system.

From a strategic perspective, digital student identification cards represent an investment that combines sustainability, economic efficiency, and cybersecurity with an enhanced user experience. For higher education institutions, they provide measurable financial savings and greater operational agility, while for students, they represent a unified, secure, and environmentally responsible gateway to academic and extracurricular services.

However, digital student identification cards also present several potential disadvantages. Implementing digital identification assumes that all students have a smartphone with a sufficiently modern operating system, which may not always be the case. In addition, the usability of mobile identification cards depends directly on the mobile device's functionality. If the device becomes unavailable, for example, due to a depleted battery, malfunction, or theft, students may temporarily lose access to university facilities, student services, or public transport. Digital identification systems also expand the potential attack surface by incorporating mobile operating systems, network infrastructure, and cloud services, thereby introducing additional cybersecurity risks. Although digital solutions may reduce long-term operational costs, their implementation typically requires substantial initial investments in licensed software, certified readers, upgrades to access control systems, and staff training. Furthermore, the implementation of such systems must ensure full compliance with the European General Data Protection Regulation and relevant national data protection legislation. Changes to operational processes, including the digital revocation of access rights or the storage of access logs, often require revisions of internal regulations, privacy impact assessments, and the establishment of new incident management procedures.

2.3 European Student Card

The development of digital student identification systems in Europe is closely connected with broader initiatives aimed at supporting the digital transformation of higher education and facilitating international student mobility. One of the most

important initiatives in this context is the European Student Card Initiative (ESCI), launched by the European Commission as part of the Erasmus+ programme. Its objective is to strengthen individuals' knowledge and skills while promoting employability, social inclusion, and active citizenship. The programme facilitates mobility for students, learners, and staff, as well as cooperation between educational institutions and organisations. In recent years, particular emphasis has been placed on digital transformation, inclusion, and sustainability (European Commission, 2024a).

The European Student Card Initiative comprises three main components that support the digitalisation of student mobility within the European Higher Education Area. The European Student Card represents a digital extension of existing student identification cards and enables students to use a single credential during international mobility to access rights and services both at host higher education institutions and within the surrounding local environment (European Commission, 2025a). The Erasmus+ Mobile App serves as a unified digital tool that supports students throughout all administrative processes related to mobility, including the phases before departure, during their stay abroad, and after completing the programme, by providing access to relevant information, enabling the submission of documentation, and allowing students to monitor the progress of their mobility in a single user-friendly environment. In addition, Erasmus Without Paper enables the digital integration of existing higher education information systems to support the fully electronic management of all phases of Erasmus+ mobility. Through standardised application programming interfaces (APIs), the system enables the secure exchange of student data between institutions, thereby reducing the need for paper documentation and analogue administrative procedures (European Commission, 2025a). An example of a physical and digital student identification card that includes elements of the European Student Card is presented in Figure 4.

Overall, the initiative aims to support the sustainable and digital transformation of the Erasmus+ programme by introducing paperless administrative processes. It is based on the “once-only” principle, meaning that data should be entered only once and subsequently reused across systems, thereby enabling more efficient management of mobility processes. In addition, the initiative promotes greater student engagement through targeted and proactive communication, thereby improving the programme's accessibility. Comprehensive digital support also

enables a smoother and more integrated mobility experience and strengthens the sense of a shared European student identity (European Commission, 2025c).

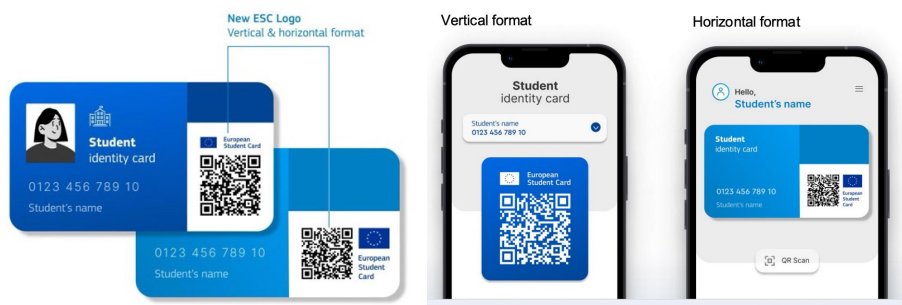


Figure 4: Example of a physical and digital student identification card that includes elements of the European Student Card

Source: (European Commission, 2025b; European Commission, 2024b)

The functionality of the European Student Card is supported by a standardized technical infrastructure designed to ensure interoperability between higher education institutions. One of the central elements of this infrastructure is the European Student Card Number (ESCN), which serves as a unique identifier for each student card (European Commission, 2025b). The identifier enables reliable identification and verification of student status across institutional systems.

In addition to the ESCN, the European Student Identifier (ESI) plays an important role in the digital identification of students within the European higher education ecosystem. The ESI enables the consistent identification of students participating in international mobility programmes and supports the secure exchange of identity-related information between universities (European Commission, 2025b).

The issuance and management of European Student Cards are supported through the ESC Router, a centralised digital platform that enables higher education institutions to issue and verify student credentials. It allows higher education institutions and other authorised issuers to manage student cards efficiently. In addition, the system supports real-time verification of student status, thereby enabling providers of student services to securely and reliably identify users. The platform is designed in accordance with European data protection standards. It

represents the technical core of the European Student Card infrastructure (European Commission, 2024b).

Higher education institutions across Europe are gradually integrating the European Student Card into their identification systems. The implementation of the initiative varies across countries and institutions, depending on the level of digital infrastructure and institutional readiness for digital transformation.

Some countries have introduced national solutions that fully comply with the requirements of the European Student Card Initiative. For example, Croatia has implemented a digital student identification system that integrates both physical and mobile versions of student identification cards. These cards enable students to access various university services and student benefits while ensuring compatibility with the European Student Card infrastructure (Bajić & Orel, 2025).

Similar developments can be observed at the institutional level across Europe. Universities such as the Complutense University of Madrid have integrated the European Student Card into their existing student identification systems, enabling students to identify themselves digitally when accessing institutional services or participating in mobility programmes (2025). Another example is Ludwig-Maximilians-Universität München (LMU) in Germany, which has implemented the European Student Card by integrating ESC elements into its existing physical student card. The ESC logo has been added to the LMUcard, symbolising compliance with European standards and enabling participation in the broader European digital identification ecosystem (Ludwig-Maximilians-Universität München, 2025).

The continued development of digital student identity systems is closely linked with broader efforts to create integrated digital infrastructures within the European Higher Education Area. Future developments are expected to focus on increasing interoperability between institutional systems, expanding the functionality of digital credentials, and improving the user experience for students participating in international mobility programmes.

An example of such developments is eduTAP, which represents an important advancement in the European Student Card ecosystem. The initiative addresses key challenges in student mobility, access to services, and digital identity management across the European Higher Education Area. It contributes to the digital transformation of higher education institutions, particularly through the transition from physical cards to digital wallets on students' smartphones (EUGLOH, 2025).

Overall, projects like eduTap represent an important step toward the digital integration of higher education systems in Europe. By enabling interoperable digital identification systems and supporting the digitalisation of mobility processes, the project contributes to the development of a more connected, efficient, and sustainable European higher education environment.

2.4 Technology Acceptance Model

The adoption and effective use of digital technologies depend not only on technological capabilities but also on users' willingness to accept and use such systems. Understanding the determinants of technology acceptance has therefore become an important area of research in information systems. One of the most widely applied theoretical frameworks for explaining user acceptance of information technology is the Technology Acceptance Model (TAM), originally proposed by Davis (Sternad Zabukovšek, Tominc, Štrukelj, & Bobek, 2020).

Fred D. Davis developed the model as an extension of the Theory of Reasoned Action (TRA), adapted specifically to the context of information systems use (Sternad Zabukovšek, Tominc, Štrukelj, & Bobek, 2020). Davis (1993) sought to explain why individuals accept or reject the use of an information system and how system design characteristics influence user acceptance. Perceived usefulness (PU) is defined as the degree to which an individual believes that using a particular system will improve their job performance. This definition is rooted in an organisational context in which individuals are rewarded for higher work performance, thereby increasing the importance of the technology's perceived usefulness (Davis, 1989; Pfeffer, 1982; Schein, 1980; Vroom, 1964). Perceived ease of use (PEOU) is defined as the degree to which an individual believes that using a system requires little effort. Davis emphasises that effort is a limited resource; consequently, users are more likely to accept systems that require less cognitive and physical effort (Davis, 1989).

Furthermore, TAM emphasises that actual system use is also determined by the user's behavioural intention to use the system (BI) (Sternad Zabukovšek, Tominc, Štrukelj, & Bobek, 2020). Behavioural intention represents the direct antecedent of actual use and reflects an individual's willingness to use the technology. This intention is formed based on the user's attitude toward using the system (AT) and the perceived usefulness of the system (Sternad Zabukovšek, Tominc, Štrukelj, & Bobek, 2020; Sternad Zabukovšek & Bobek, 2025).

It is also important to highlight the existence of external variables, which indirectly affect the use of an information system through perceived usefulness and perceived ease of use (Sternad Zabukovšek, Tominc, Štrukelj, & Bobek, 2020). These external variables are not specified in advance, as their selection depends on the research context and the type of technology under investigation (Sternad Zabukovšek & Bobek, 2025).

Beyond external variables, an important limitation of the original TAM in institutional contexts is its assumption of voluntary use. The model was originally developed for basic office software adoption in the workplace in voluntary-use contexts, and its core construct of BI presupposes that users freely choose how and to what degree they engage with a technology (Sternad Zabukovšek & Samo, 2023). The absence of subjective norms, that is, the influence of social and institutional pressures, is considered one of the primary weaknesses of the basic TAM model (Sternad Zabukovšek & Samo, 2023). This is directly relevant to the context of digital student identification cards, where institutional adoption may be partially or fully mandatory: students may be required to use the system regardless of their personal attitudes or intentions. In such contexts of mandatory use, the decision to select and implement the technology is typically made at the organisational or institutional level, and users are expected to comply in their daily activities. The fundamental TAM assumption that users have a genuine choice over the extent to which they will adopt a technology therefore, does not hold under conditions of mandatory institutional use (Sternad Zabukovšek & Samo, 2023).

Furthermore, empirical research in mandatory use contexts has confirmed that important differences exist between voluntary and mandatory use contexts in terms of the relationships between TAM constructs. Perceived ease of use is not always statistically significantly associated with attitude toward use or perceived usefulness,

a pattern observed across multiple ERP implementation studies, suggesting that when system use is compulsory, ease of use loses its predictive relevance (Sternad Zabukovšek & Samo, 2023).

Subsequent research has extended the original TAM framework by incorporating additional factors that may influence technology adoption in different contexts. For example, Venkatesh and Davis (2000) proposed an extension of the model (TAM2) that introduced additional determinants of perceived usefulness (PU) and behavioural intention (BI). Later, the Unified Theory of Acceptance and Use of Technology (UTAUT) integrated several existing technology acceptance models, including TAM, in order to explain user adoption of information systems across different organisational contexts (Venkatesh, Morris, Davis, & Davis, 2003). In addition to these theoretical developments, researchers have increasingly emphasized the importance of contextual factors, such as trust in the security and reliability of digital systems, particularly in environments where technologies process personal or identity-related data (Sternad Zabukovšek & Bobek, 2025).

In the context of digital student identification cards, trust is particularly relevant because such systems handle identity-related information and may be integrated with various institutional services and access control mechanisms. If users perceive the system as secure and trustworthy, they may be more likely to view the technology as useful and to adopt it in practice.

Based on these theoretical foundations, TAM provides an appropriate framework for examining students' acceptance of digital student identification cards. The model enables the analysis of relationships between perceived usefulness, perceived ease of use, attitudes toward use, behavioural intention, and trust in the security of the digital system. These constructs form the basis for the research model and hypotheses presented in the following sections of the chapter.

The growing adoption of digital identity systems in higher education institutions raises important questions about students' acceptance and use of such technologies. Although digital student identification cards offer various operational and technological advantages, their successful implementation depends largely on users' willingness to adopt and use the system. Understanding the factors that influence

students' acceptance of digital student identification cards is therefore essential for the effective implementation of such solutions within university environments.

2.5 Methods and research process

Based on a review of the literature on information technology adoption, particularly the Technology Acceptance Model (TAM), a research model was developed to examine the factors influencing students' adoption of digital student identification cards. The research model used in this study is presented in Figure 5 and is grounded in the core structure of TAM. However, the model was conceptually adapted to the specific context of digital student identification cards and extended to include an additional construct representing trust in the system's security. The inclusion of this construct aims to capture the dimension of perceived security, which is frequently identified in the literature as an important determinant of technology adoption, particularly in the context of digital identities and digital services.

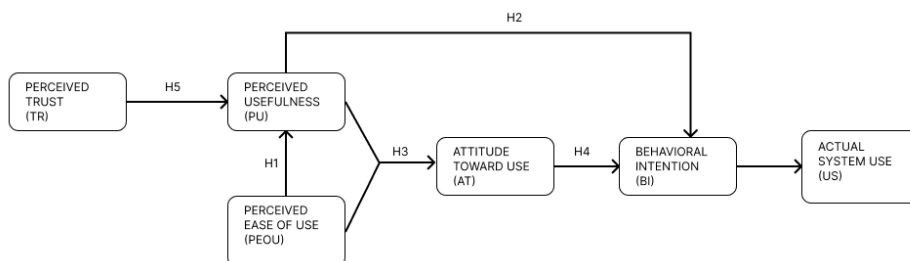


Figure 5: Research model

Source: Author's own work.

Within the model, perceived ease of use (PEOU) represents the degree to which users believe that using the digital student identification card is effortless and requires minimal additional effort. Perceived usefulness (PU) reflects users' beliefs that using the digital student identification card improves their efficiency or provides tangible benefits in everyday student life. Attitude toward use (AT) represents the overall positive or negative evaluation of using the digital student identification card, while behavioural intention (BI) indicates users' willingness to use the solution. The outcome construct of the model is the actual use of the system (US).

Based on the theoretical foundations of TAM and the conceptual research model presented above (Figure 5), the following hypotheses are formulated and tested in the empirical part of the study.

H₁: Perceived ease of use of the digital student identification card (PEOU) has a statistically significant positive effect on perceived usefulness of the digital student identification card (PU).

H₂: Perceived usefulness of the digital student identification card (PU) has a statistically significant positive effect on behavioural intention to use the digital student identification card (BI).

H₃: Perceived usefulness and perceived ease of use of the digital student identification card (PU, PEOU) have a statistically significant positive effect on attitude toward using the digital student identification card (AT).

H₄: Attitude toward using the digital student identification card (AT) has a statistically significant positive effect on behavioural intention to use the digital student identification card (BI).

H₅: Trust in the security of the digital student identification card (TR) has a statistically significant positive effect on perceived usefulness of the digital student identification card (PU).

The proposed research model assumes several direct and indirect relationships between the constructs. In accordance with TAM, perceived ease of use (PEOU) is expected to positively influence perceived usefulness (PU), and both are assumed to affect users' attitudes toward use (AT). Furthermore, attitudes toward use (AT) and perceived usefulness (PU) are expected to influence behavioural intention (BI), which serves as the immediate antecedent of actual system use (US). Additionally, trust in the security of the digital student identification card is assumed to positively influence perceived usefulness (PU), as users tend to perceive secure systems as more reliable and beneficial.

This study adopts a quantitative research approach to examine the factors influencing students' acceptance of digital student identification cards. A structured survey questionnaire was used as the primary data collection instrument. The questionnaire was designed to measure students' perceptions of the key constructs included in the research model, namely perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (AT), behavioural intention to use (BI), trust in the security of the digital student identification card (TR), and actual system use (US).

The empirical data were collected from students enrolled in higher education institutions. Participation in the survey was voluntary and anonymous, and no personal or demographic data were collected in order to ensure full respondent anonymity. The collected data were analysed using quantitative statistical methods to evaluate relationships among the constructs in the research model and test the proposed research hypotheses.

The questionnaire consisted of several items corresponding to the constructs defined in the research model. The measurement items were designed to capture students' perceptions of perceived usefulness, perceived ease of use, attitude toward using the system, behavioural intention to use the system, and trust in the security of the digital student identification card. In addition, the questionnaire included a question measuring the actual use of the student identification card, distinguishing between the physical and digital forms of the card.

The constructs of perceived usefulness (PU) and perceived ease of use (PEOU) were derived from the Technology Acceptance Model (Davis, 1989), while the trust construct was included due to the importance of security perceptions in digital identity systems (Sternad Zabukovšek & Bobek, 2025). The measurement items were adapted to reflect the specific context of digital student identification cards and the services associated with their use.

Most questionnaire items were measured using a five-point Likert scale ranging from 1 ("very low") to 5 ("very high"), allowing respondents to indicate the extent to which they perceive benefits and ease of use associated with digital student identification cards. In addition, the questionnaire included selected single-item measures and a question asking respondents to identify the form of student identification card they most frequently use.

In this study, several constructs were measured using single-item indicators. Although multi-item scales are commonly recommended for measuring TAM constructs, single-item measures can be acceptable in exploratory studies and when the research objective is to capture respondents' general perceptions of a specific system feature (Hair, Black, Babin, & Anderson, 2019). Given the exploratory nature of this study and the relatively short questionnaire designed to encourage participation, selected constructs were therefore operationalised using single-item indicators. The measurement constructs and questionnaire items used in the study are presented in Table 1.

Table 1: Measurement constructs and questionnaire items

Construct	Code	Measurement item	Source
Actual system use	US1	Which form of student identification card do you use most frequently?	(Davis, 1989).
Behavioural intention to use	BI1	How likely would you be to recommend the use of a digital student identification card to students who currently use a physical card?	(Davis, 1989).
Attitude toward using the system	AT1	I prefer the digital student identification card to the physical one.	(Davis, 1989).
Perceived ease of use	PEOU1	Ease of use.	(Davis, 1989).
Perceived usefulness	PU1	Benefit: identification	(Davis, 1989).
	PU2	Benefit: borrowing books	(Davis, 1989).
	PU3	Benefit: student discounts	(Davis, 1989).
	PU4	Benefit: access to study rooms or other facilities	(Davis, 1989).
	PU5	Benefit: use of subsidized student meals	(Davis, 1989).
	PU6	Benefit: attendance recording	(Davis, 1989).
Perceived trust	TR1	Do you trust the security of the digital student identification card?	(Sternad Zabukovšek & Bobek, 2025)

Source: Author's own work.

3 Research results

3.1 Sample description

The target population of this study consisted of students enrolled at three major public universities in Slovenia: the University of Ljubljana, the University of Maribor, and the University of Primorska. These institutions represent the largest higher education providers in the country and cover a wide range of study programmes and academic disciplines.

The survey was distributed via the university's mobile applications, accessible only to users with valid university digital identities. This distribution channel ensured that only authenticated university users could access the questionnaire, thereby providing a reliable mechanism for reaching the intended student population.

In total, the questionnaire was opened by 560 students, of whom 198 respondents completed the survey in full, resulting in a completion rate of approximately 35%. Given the voluntary nature of participation and the relatively short questionnaire, the achieved response rate is satisfactory.

An initial screening question was used to identify the most frequently used form of student identification card among respondents. Out of the 198 respondents who completed the questionnaire, 64 indicated that they primarily use a digital student identification card. Since the objective of this study is to examine the acceptance of digital student identification cards, only these respondents were included in the subsequent empirical analysis. Consequently, the final analytical sample consisted of 64 students.

This relatively small sample represents a significant methodological limitation. It reduces the statistical power of the regression analyses, meaning that some hypothesised relationships may not have reached significance due to insufficient power rather than a true absence of effect. The findings should therefore be interpreted with caution and cannot be generalised to the broader student population without replication in larger and more diverse samples.

The collected dataset was subsequently used for statistical analyses to examine the relationships among the constructs included in the research model.

3.2 Factor analysis

An exploratory factor analysis (EFA) was used to examine the instrument's internal structure and assess the internal structure of the constructs included in the study. The purpose of factor analysis is to evaluate whether the observed variables used to operationalise a construct converge into one or more latent dimensions (Tominc, Čančer, & Rožman, 2018). According to Hair et al. (2019), constructs included in factor analysis should ideally be measured using at least five observed variables.

It should be noted that the factor analysis and subsequent hypothesis testing were conducted on a subsample of $N = 64$ respondents who actively use digital student identification cards. These respondents therefore provided relevant evaluations of the constructs examined in this study. Although the sample size is relatively small, it meets the commonly recommended minimum ratio of observations to variables in the factor analysis (Hair, Black, Babin, & Anderson, 2019).

Among the constructs included in the Technology Acceptance Model (TAM) presented in Table 1, only the Perceived usefulness (PU) construct met the requirement of at least 5 measurement items, with 6 items (PU1–PU6). Other constructs in the research model (such as Perceived ease of use and Behavioural Intention) were measured with fewer items and were therefore excluded from the factor analysis. For this reason, the factor analysis was conducted only for the construct Perceived Usefulness, which contained a sufficient number of measurement items to allow an exploratory examination of its internal structure. The analysis, therefore, served primarily as a preliminary assessment of the measurement instrument, rather than a full validation of the measurement model.

The primary objective of the factor analysis was to determine whether the items PU1–PU6 empirically converge into a latent factor representing Perceived usefulness. For this purpose, an exploratory factor analysis was conducted on the six measurement items using Principal Component Analysis with Varimax rotation.

Correlation analysis indicated that most variables were moderately and positively correlated, suggesting that the data were suitable for factor analysis. The suitability of the data was further confirmed by the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (KMO = 0.614) and Bartlett’s test of sphericity, which was statistically significant ($p < 0.001$).

The initial analysis indicated that one item (PU3) had a communality below the recommended threshold of 0.40 and was therefore excluded from further analysis. After removing this item, the factor analysis was repeated using the remaining variables. The revised dataset continued to meet the assumptions for factor analysis (KMO = 0.589; Bartlett’s test $p < 0.001$).

The results revealed a two-factor structure, as indicated by the KMO criterion (eigenvalues > 1), accounting for 68.667% of the total variance. To improve interpretability, the factor solution was rotated using the Varimax rotation method. The rotated factor matrix showed a clear distinction between the two item groups. The first factor included items PU1, PU2, and PU6, which reflect the perceived usefulness of the administrative functions of the student identification card. The second factor consisted of items PU4 and PU5, which relate to the perceived usefulness of student services.

These findings indicate that students perceive the usefulness of digital student identification cards as a multidimensional construct, distinguishing between administrative and service-related benefits. The identified two-factor structure also suggests that students differentiate between the usefulness of digital student identification cards for administrative purposes and their usefulness for accessing various student services.

Finally, reliability analysis of the perceived usefulness (PU1, PU2, PU4, PU5, PU6) yielded a Cronbach’s alpha of 0.655, indicating moderate internal consistency. This suggests that the items included in the construct measure the perceived usefulness of digital student identification cards in a reasonably consistent manner. Although the reliability coefficient is slightly below the commonly recommended threshold of 0.70, it can be considered acceptable for exploratory research and preliminary measurement scales, particularly in studies with relatively small samples (Hair, Black, Babin, & Anderson, 2019).

3.3 Hypothesis testing

To test the proposed hypotheses, regression analysis was conducted using SPSS. The relationships among the constructs in the research model were analysed to determine whether the hypothesised effects were statistically significant.

Because the exploratory factor analysis revealed two distinct dimensions of perceived usefulness, namely perceived usefulness of administrative functions and perceived usefulness of student services, the hypotheses involving perceived usefulness were tested separately for these two dimensions. Consequently, several hypotheses were divided into sub-hypotheses in order to account for this multidimensional structure.

Hypothesis H₁ examined whether perceived ease of use (PEOU) of the digital student identification card influences perceived usefulness (PU). Two regression analyses were conducted for the two dimensions of perceived usefulness. The results indicated that perceived ease of use did not have a statistically significant effect on either the perceived usefulness of administrative functions ($\beta = 0.035$, $R^2 = 0.001$, $p = 0.787$) or the perceived usefulness of student services ($\beta = 0.176$, $R^2 = 0.031$, $p = 0.163$). Therefore, hypotheses H_{1a} and H_{1b} were not supported.

Hypothesis H₂ investigated whether perceived usefulness influences behavioural intention (BI) to use the digital student identification card. Separate regression analyses were conducted for the two dimensions of perceived usefulness. The results showed that neither the perceived usefulness of administrative functions ($\beta = -0.120$, $R^2 = 0.014$, $p = 0.344$) nor that of student services ($\beta = 0.011$, $R^2 = 0.000$, $p = 0.932$) had a statistically significant effect on behavioural intention. Consequently, hypotheses H_{2a} and H_{2b} were not supported.

Hypothesis H₃ examined the influence of perceived ease of use (PEOU) and perceived usefulness (PU) on attitudes toward using the digital student identification card (AT). The overall regression model (H_{3a}) was statistically significant ($R^2 = 0.232$, $p = 0.001$). More specifically, perceived ease of use had a statistically significant positive effect on attitudes toward use ($\beta = 0.311$, $R^2 = 0.097$, $p = 0.012$), as did perceived usefulness of administrative functions ($\beta = 0.369$, $R^2 = 0.136$, $p = 0.003$). In contrast, perceived usefulness of student services did not have a statistically

significant effect on attitudes toward use ($\beta = 0.132$, $R^2 = 0.018$, $p = 0.297$). Consequently, hypotheses H_{3b} and H_{3c} were supported, while H_{3d} was not supported.

Hypothesis H_4 analysed whether attitudes toward using the digital student identification card influence behavioural intention to use it. The regression analysis showed no statistically significant relationship between attitudes toward use and behavioural intention ($\beta = 0.000$, $R^2 = 0.000$, $p = 0.998$). Therefore, H_4 was not supported.

Finally, Hypothesis H_5 examined whether trust in the security of the digital student identification card influences perceived usefulness. Two regression analyses were again conducted for the two dimensions of perceived usefulness. The results indicated that trust in security had a statistically significant positive effect on the perceived usefulness of administrative functions ($\beta = 0.369$, $R^2 = 0.136$, $p = 0.003$). However, no statistically significant effect was observed for the perceived usefulness of student services ($\beta = 0.132$, $R^2 = 0.018$, $p = 0.297$). Consequently, H_{5a} was supported, whereas H_{5b} was not supported.

The detailed results of the regression analyses are presented in Table 2.

Table 2: Results of hypothesis testing

Hypothesis	Relationship	Beta (β)	R^2	p-value	Result
H_{1a}	PEOU $\rightarrow$ PU (Administrative functions)	0.035	0.001	0.787	Not supported
H_{1b}	PEOU $\rightarrow$ PU (Student services)	0.176	0.031	0.163	Not supported
H_{2a}	PU (Administrative functions) $\rightarrow$ BI	-0.120	0.014	0.344	Not supported
H_{2b}	PU (Student services) $\rightarrow$ BI	0.011	0.000	0.932	Not supported
H_{3a}	PEOU + PU (Admin) + PU (Services) $\rightarrow$ AT	–	0.232	0.001	Supported
H_{3b}	PEOU $\rightarrow$ AT	0.311	0.097	0.012	Supported
H_{3c}	PU (Administrative functions) $\rightarrow$ AT	0.369	0.136	0.003	Supported
H_{3d}	PU (Student services) $\rightarrow$ AT	0.132	0.018	0.297	Not supported
H_4	AT $\rightarrow$ BI	0.000	0.000	0.998	Not supported

Hypothesis	Relationship	Beta (β)	R ²	p-value	Result
H _{5a}	Trust (Security) → PU (Administrative functions)	0.369	0.136	0.003	Supported
H _{5b}	Trust (Security) → PU (Student services)	0.132	0.018	0.297	Not supported

Source: Author's own work.

Overall, the results indicate that perceived ease of use and the perceived usefulness of administrative functions play the most important role in shaping students' attitudes toward digital student identification cards. In contrast, several other relationships proposed by the Technology Acceptance Model were not statistically supported in the analysed sample.

4 Discussion

The aim of this study was to examine the factors influencing students' acceptance of digital student identification cards in higher education institutions using the Technology Acceptance Model. The results of the empirical analysis provide several important insights into how students perceive the usefulness, usability, and security of digital identity systems, which are increasingly part of universities' digital infrastructure.

The exploratory factor analysis revealed that students do not perceive the usefulness of digital student identification cards as a strictly one-dimensional construct. Instead, the results indicate a distinction between the administrative usefulness of the card, related to identification and access management functions, and its service-related usefulness, associated with access to various student services. This finding suggests that digital student identification systems simultaneously fulfil two complementary roles within higher education institutions. On the one hand, they serve as part of the core digital identity infrastructure, enabling secure authentication, access control, and institutional governance. On the other hand, they may act as a platform for integrating various student services, facilitating access to campus facilities, transportation systems, and other student benefits. Interestingly, the results further suggest that students assign greater importance to the administrative functions of the digital student identification card than to its service-related functionalities.

The results of the hypothesis testing further reveal an interesting pattern in the relationships proposed by the Technology Acceptance Model. While perceived ease of use and the perceived usefulness of administrative functions significantly influenced students' attitudes toward the use of digital student identification cards, several relationships commonly observed in TAM studies were not supported. In particular, perceived usefulness did not significantly influence behavioural intention, and attitudes toward use did not significantly predict behavioural intention. One possible explanation for these results lies in the specific institutional context in which digital student identification systems are used. Unlike many digital technologies examined in previous TAM studies, the use of student identification systems is often embedded within institutional processes and may therefore not be entirely voluntary. Students may rely on the system regardless of their behavioural intentions because it is required for accessing university facilities, services, or administrative procedures. Similar patterns have been observed in studies of organisational information systems, where system use is integrated into institutional processes and behavioural intention may therefore play a less significant role in explaining actual system use (Davis, 1989; Sternad Zabukovšek et al., 2020; Sternad & Bobek, 2023, 2025).

Further analysis of the results shows that perceived ease of use has a statistically significant positive influence on students' attitudes toward the use of digital student identification cards. This finding is consistent with the core assumptions of the Technology Acceptance Model (Davis, 1989) and its later extensions (Venkatesh & Davis, 2000), which emphasise the importance of usability and simplicity in shaping users' perceptions of new technologies. In the context of higher education, this suggests that students are more likely to develop positive attitudes toward digital identity solutions when these systems are intuitive and easy to use. Since digital student identification cards are typically implemented through mobile applications or integrated campus systems, the usability of these platforms plays an important role in shaping students' perceptions and acceptance.

The results also indicate that only the perceived usefulness of administrative functions significantly influences students' attitudes toward the use of digital student identification cards. In contrast, the perceived usefulness of student services does not have a statistically significant effect. This suggests that students primarily perceive digital identification systems as tools that facilitate administrative and institutional processes, such as identification, access to facilities, or authentication

procedures, rather than as platforms that provide additional service-oriented functionalities. In addition, the findings show that trust in the security of the digital student identification card significantly influences the perceived usefulness of administrative functions. Since digital identity systems process sensitive personal data and play a central role in identity verification and access management, trust in system security appears to be an important factor shaping students' perceptions of their usefulness. This finding suggests that students primarily perceive digital student identification cards as instruments that support institutional and administrative processes rather than as platforms for accessing additional digital services. In this sense, the usefulness of digital student identity systems appears to be driven mainly by their role in facilitating core identification and access management functions within the university environment.

From a broader perspective, these findings can be interpreted within the context of the ongoing digital transformation of higher education institutions. Universities increasingly rely on integrated digital infrastructures that support administrative processes, identity management, and access to institutional services. Digital student identification systems represent an important component of this infrastructure, enabling secure identification, service integration, and more efficient governance processes within universities. Digital student identity systems can therefore also be interpreted as governance technologies that support more transparent and accountable institutional processes. By enabling reliable digital authentication and traceability of service access, such systems may strengthen institutional governance mechanisms and support compliance with regulatory frameworks. In this sense, digital student identity infrastructures contribute not only to operational efficiency but also to the broader objectives of sustainable governance within higher education institutions.

The findings of this study also contribute to the existing literature on technology acceptance by providing additional insights into the application of the Technology Acceptance Model in the context of digital identity systems in higher education. While TAM has been widely applied to examine the adoption of various digital technologies, the results of this study suggest that the relationships among its core constructs may differ when technologies constitute institutional digital infrastructure rather than purely voluntary systems. In such contexts, system use is often embedded in organisational processes, which may reduce the predictive value of behavioural

intention for technology adoption. Instead, factors such as system usability, trust in system security, and the perceived usefulness of administrative functions appear to play a more significant role in shaping users' perceptions and attitudes toward the system.

Several practical implications for higher education institutions implementing digital student identification systems follow from these findings. Universities should pay particular attention to the usability of digital student identification solutions, as perceived ease of use significantly influences students' attitudes toward the system. Digital identity systems integrated into mobile applications or campus platforms should therefore be designed to ensure simple, intuitive, and reliable user interaction. Furthermore, universities should ensure that digital identification systems effectively support core functions such as authentication, access management, and identification across institutional services. Finally, since digital identity solutions involve the management of sensitive personal data, higher education institutions should ensure high standards of data protection, transparent privacy policies, and robust cybersecurity measures to strengthen students' trust in the system and increase its perceived usefulness.

Overall, the findings highlight the importance of considering the institutional context when analysing the acceptance of digital technologies in higher education. Digital student identification cards are an integral component of universities' digital transformation, enabling secure identification, service access, and the integration of administrative and student support processes. As universities increasingly adopt integrated digital identity solutions, understanding the factors that influence users' perceptions of these systems becomes essential for ensuring their successful implementation and long-term sustainability.

This study adds to the existing literature on technology acceptance by examining TAM in a context where the technology constitutes institutional digital infrastructure rather than a purely voluntary system. While TAM has traditionally been applied to voluntary information systems used in organisational or consumer contexts, digital identity systems in higher education constitute a specific category of technologies often embedded within institutional processes. As a result, user behaviour may be influenced not only by individual perceptions of usefulness and ease of use, but also by institutional requirements and infrastructural dependencies. This suggests that

technology acceptance models may operate differently in contexts where system use is partially institutionalised.

Collectively, these findings advance the understanding of digital identity systems in higher education by providing empirical insights into the factors shaping students' perceptions of digital student identification cards. In particular, the findings highlight the importance of administrative usefulness, system usability, and trust in system security in shaping students' attitudes toward digital identity systems. By showing that traditional TAM relationships may operate differently in the context of institutional digital infrastructure, this study contributes to a better understanding of technology acceptance in organisational and governance-related digital systems.

5 Conclusion

The objective of this study was to examine the factors influencing students' acceptance of digital student identification cards in higher education institutions. Drawing on the TAM, the study analysed the relationships between perceived ease of use, perceived usefulness, trust in system security, attitudes toward using the system, and behavioural intention. The empirical analysis was based on survey data collected from students at three Slovenian universities.

The results indicate that perceived ease of use plays an important role in shaping students' attitudes toward the use of digital student identification cards. Students who perceive the system as simple and intuitive are more likely to develop positive attitudes toward its use. Furthermore, the study shows that perceived usefulness is not a single-dimensional construct. Two distinct dimensions were identified: the perceived usefulness of administrative functions and that of student services. The findings suggest that administrative functionalities of the digital student identification card have a stronger influence on students' attitudes than additional service-related features.

The analysis also revealed that trust in the security of the digital student identification card positively influences the perceived usefulness of administrative functions. This result highlights the importance of security and reliability in digital identity systems, particularly in institutional environments where such systems are used for identification and access management. Overall, the findings suggest that the

acceptance of digital student identification systems is influenced primarily by system usability, trust in system security, and the perceived usefulness of administrative functions.

From the perspective of higher education governance, digital student identification cards represent an important component of universities' digital infrastructure. These systems enable secure identification, facilitate access to institutional services and facilities, and support the integration of various digital platforms within the university environment. As universities continue to implement digital technologies across their administrative and academic processes, digital identity systems may increasingly play an important role in supporting efficient, transparent, and sustainable institutional governance. From an environmental perspective, such systems reduce the need for physical plastic cards and associated material resources, thereby lowering waste, while from a governance perspective, they support more transparent and traceable administrative processes, strengthen data integrity, and enable more effective institutional oversight. By reducing reliance on physical materials, simplifying administrative processes, and enabling integrated digital service ecosystems, such systems support more efficient resource management and environmentally responsible institutional practices. Consequently, digital student identification infrastructures represent an important element of the ongoing digital transformation of universities and their transition toward more sustainable and digitally enabled governance models.

Despite these contributions, this study has several limitations that should be considered when interpreting the results. First, the empirical analysis was conducted on a relatively small sample of students who actively use digital student identification cards. As the final analytical sample consisted of 64 respondents, the findings should be interpreted as indicative rather than fully representative of the broader student population.

Second, in order to ensure full anonymity and comply with ethical research principles, the questionnaire did not collect detailed demographic information about respondents. Consequently, the analysis could not examine potential differences between demographic groups. Finally, the survey instrument was originally developed for a different study (Hajdenkumer, 2025) and was not specifically

designed to measure TAM constructs, which limits the precision of their operationalisation.

Future research could address these limitations by including larger, more diverse student samples and collecting demographic data that enable subgroup analyses. In addition, future studies could employ measurement instruments specifically designed to capture TAM constructs using validated scales. Comparative studies across different universities or countries could also provide further insights into how digital student identification systems are implemented and accepted in different higher education environments.

Overall, this study contributes to a better understanding of how students perceive digital identity systems in higher education and highlights the importance of usability, trust, and administrative usefulness for the successful implementation of digital student identification infrastructures. In this context, digital student identity systems should not be viewed merely as technological tools for identification but rather as strategic digital infrastructures that support the integration of administrative processes, enhance service accessibility, and contribute to more efficient and sustainable governance in higher education institutions.

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KNOWLEDGE ARCHITECTURE FOR VIABLE SUSTAINABILITY DISCLOSURE

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Sustainability disclosure is frequently perceived as an obligation to report. Yet its credibility is contingent upon the organisational framework that fosters and underpins sustainability-related knowledge. This conceptual chapter highlights the vital role of knowledge architecture in sustainable governance. The study argues that a weak knowledge architecture may increase stakeholder scepticism and the risk of greenwashing. To address these challenges, the study proposes a comprehensive framework within which codification standards, shared taxonomies and ontologies, boundary objects, and traceability mechanisms are needed to enhance the viability of sustainability reporting. Therefore, the originality of the present work lies in proposing an innovative conceptual framework that provides a practical and dynamic tool for researchers, professionals, and policymakers in the construction of knowledge architectures that ensure that sustainability claims are coherent, verifiable, and manageable (in other words, viable).

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1 Introduction

In the last decade, sustainability disclosure has evolved from a marginal communication tactic to a pivotal element of corporate credibility (MacLean & Rebernak, 2007; Cepêda et al., 2025). As sustainability issues gain more attention, organizations are facing heightened expectations, making transparency and accountability key in how they connect with various stakeholders (Saviano et al., 2017, 2025; Caputo et al., 2020). In this landscape, concerns regarding the reliability of sustainability disclosures have become a matter of significant importance (Utz, 2019). However, despite the proliferation of sustainability narratives, this has not necessarily resulted in a concomitant increase in trust. Indeed, when claims lack clarity or verifiability, there is a tendency for skepticism to increase, thus creating opportunities for vague or misleading sustainability messages (Caputo et al., 2018, 2020).

A pervasive misconception appears to persist in both management practices and selected academic discourses. Sustainability disclosure is frequently regarded as a mere reporting obligation, as if the sheer augmentation of indicators, pages, or dashboards would inherently enhance credibility. However, it should be noted that disclosure barely represents the initial phase of a more extensive process. The veracity of sustainability claims is contingent upon the organizational framework that facilitates the creation, comprehension, harmonization across various departments, and subsequent correlation with substantial evidence and responsibility. In essence, credibility does not materialize spontaneously at the stage of reporting; rather, it is constructed earlier on by the systems that shape and manage sustainability knowledge. This perspective is in alignment with the notion that social and economic dynamics are influenced by the way systems interact to share and process information (Barile & Saviano, 2017). It has been widely recognized that many management challenges stem from fragmented information flows and inconsistent ways of interpreting data (Caputo, 2017; Caputo & Evangelista, 2018).

Sustainability data originates from various sources and owners. It is derived through operational processes, human resources practices, procurement relationships, risk management, and financial routines, and subsequently distilled into simplified metrics and narratives. Concurrently, sustainability disclosures are interpreted as subject to perpetual modification, signifying that a singular indicator may be perceived in diverse ways depending on function, industry, or stakeholder group.

This generates a considerable degree of interpretive flexibility, which in turn exposes organizations to the risk of producing reports fragile in substance. This perspective is consistent with the broader call to move beyond simplistic approaches and rethink how we manage knowledge, considering new socio-economic changes (Cillo et al., 2022).

Despite the vibrant discourse surrounding sustainability reporting, assurance, and stakeholder communication, there remains a paucity of attention accorded to the organisational “architecture” that underpins sustainability knowledge (Daugaard & Ding, 2022). In such a vein, despite numerous contributions, the shared frameworks required to elucidate the conditions for coherent, reliable, and transferable knowledge remain inadequate (Choi & Lee, 2023). In the context of sustainability, this deficiency can prove especially costly, as disclosure occurs in an environment characterised by information asymmetry, whereby external stakeholders evaluate companies based on signals that are only partially verifiable.

This chapter highlights that knowledge architecture plays a crucial (yet frequently underestimated) role in ensuring credible disclosure and fostering sustainable governance. The central argument is that the plethora of risks associated with greenwashing does not solely stem from deliberate deceit, but also from organizational structures that are deficient in terms of rigor, resulting in interpretive flexibility, misalignment between disparate functions, and discrepancies between claims and actual data (Tripathi et al., 2026).

Following the proposed conceptual path, the work presents a framework where knowledge architecture for sustainability disclosure is broken down into four interconnected components: codification standards (which include definitions, measurement guidelines, and documentation protocols), shared taxonomies and ontologies (to ensure consistent meanings across various functions and disclosure channels), boundary objects (like materiality matrices and sustainability scorecards that facilitate coordination without imposing artificial consensus), and traceability mechanisms (such as source referencing, version control, and audit-ready repositories that link claims to evidence and accountability). This perspective is consistent with the notion that value and meaning are increasingly co-created among various actors and institutional contexts (Saviano et al., 2025), particularly in contexts where engagement and participation are pivotal to fostering sustainable development pathways (Caputo et al., 2023; Collste et al., 2023).

The contribution of this chapter is threefold. Firstly, it reframes the credibility of sustainability disclosure as an architectural design problem, thereby shifting attention from the superficial nature of reporting to the infrastructural conditions that render sustainability claims coherent and verifiable (Caputo, 2017; Cillo et al., 2022). Secondly, it uses knowledge management insights to explain how interpretive discretion can be reduced through organizational design choices (Caputo & Evangelista, 2018). Thirdly, it provides a practical orientation by translating the four building blocks into design principles that can support firms in strengthening transparency and reducing greenwashing risk (Caputo et al., 2018, 2020).

The remainder of the chapter is organized as follows. The second section provides a conceptual framework for understanding sustainability disclosure as a knowledge challenge, elucidating the reasons why ambiguity and inconsistency are structurally likely to occur in the absence of adequate infrastructures. In the third section, knowledge architecture is decoded in the sustainability context, through the four constituent elements of the proposed framework, which are examined in detail. Finally, the implications for sustainable governance are discussed, and a research agenda is proposed, outlining possible empirical pathways for assessing knowledge architecture in the sustainability field and comparing configurations across industries and institutional environments.

2 Background and problem framing: sustainability disclosure as a knowledge challenge

Over time, sustainability disclosures have assumed a key role in fostering organizational credibility and long-term survival, shaping the evolutionary transition from the mere sharing of information to a process of knowledge construction that develops through the interaction among systems (Caputo et al., 2016; Perko & Mlinarič, 2016). Considering the emerging dynamics that characterize current approaches to the measurement and reporting of sustainability performance, increasingly shaped by multiple regulatory and institutional actors, the production of sustainability information is becoming progressively more complex. The democratization of knowledge enabled by the paradigm shift of digitalization, together with the implementation of numerous European Directives, has increased the “chaos” of sustainability disclosures management (Cervino & Caputo, 2025; Russo et al., 2025). As stated by Saviano et al. (2019), the growing informational complexity is largely due to the multi-source, cross-functional, and continuously

evolving nature of sustainability standards. In particular, the absence of unique guidelines, the Corporate Sustainability Reporting Directive (CSRD), and the recent proposal of the Omnibus Package represent a complex effort to promote a potentially uniform standardization of sustainability reporting (Primec & Belak, 2022).

The fragmentation of data, the interdisciplinary nature of sustainability information from multiple domains, and the multiple challenges faced by decision-makers in identifying effective interpretative schemes for managing informational endowments contribute to ambiguity and inconsistency in the acquisition, documentation, transfer, creation, and application of sustainability information (Perko, 2021). Furthermore, internal and external information asymmetries, uncertainties in measurement methodologies, governmental pressures, and interpretative flexibility increase the risks of greenwashing, undermining the credibility and effectiveness of sustainability reporting (Kumashiro, 2025). Within this evolutionary circuit, sustainability information no longer resides within a single business area, but it refers to multiple organizational functions and departments, which often struggle to establish points of contact in the logic of information transfer (Kurpierz & Smith, 2020). Moreover, the current issue is that knowledge management systems must address the proliferation of the greenwashing phenomenon, which reflects cognitive distortion in the codification, verification, and dissemination of sustainability knowledge, generating understandable cognitive resistance and erosion of stakeholder trust. Originally, the concept was defined as “the intersection of two firm behaviors: poor environmental performance and positive communication about environmental performance” (Delmas & Burbano, 2011: 4). In this context, organizations selectively communicate certain information while hiding others, intending to influence the sensemaking processes of actors engaged in sustainability (Ben Mahjoub, 2025).

According to Barile et al. (2012), because of growing information requests from supra-systems, the potential for generating cognitive, value-based, and informational dissonances increases, particularly when organizational mechanisms for managing sustainability knowledge remain weak. Several researchers and practitioners have highlighted the need to identify tools, models, and holistic approaches to manage the complex information variety within the domain of sustainability disclosures. In this vein, the spread of interdisciplinary approaches suggests that a reductionist logic still predominates in the management and communication of sustainability

information, with limited attention to the “knowledge architecture” as a lever of sustainable governance, capable of guiding the construction of meaning behind (and beyond) shared information (Caputo et al., 2016). Following this line, it becomes evident that, beyond the technical dimensions of measurement, knowledge architecture represents a still fragile yet significant paradigmatic shift in the evolution of the available literature on the theme (Daugaard & Ding, 2022).

As noted by Saviano et al. (2017), architectures play a fundamental role in supporting credible disclosure in contexts increasingly characterized by speculative and asymmetric behaviours. From a knowledge-based view perspective, knowledge codification systems could help to reduce entropy and information variety, while simultaneously mitigating knowledge-hiding practices that feed greenwashing and undermine disclosure credibility (Caputo et al., 2021).

3 Conceptualizing knowledge architecture for sustainability disclosure

3.1 From disclosure outputs to knowledge infrastructures

Sustainability disclosure can take multiple forms, including reports, websites, dashboards, ratings, and assurance statements (Darnall et al., 2022). Nevertheless, the reliability of these outputs is influenced by the organisational factors that enable the production, comprehension, and verification of sustainability information before its dissemination (Wang & Zeng, 2024). The challenges experienced by managers in such contexts are frequently attributed to the disconnection or influence of conflicting interpretative frameworks (Caputo, 2017). In the context of the sustainability landscape, fragmentation is not merely a marginal concern; it is an inherent feature of the system itself. Sustainability-related information originates from a variety of practices, including operations, procurement, human resources, compliance, risk management, and finance (Craig & Allen, 2013). These disparate elements are subsequently amalgamated to form overarching indicators and narratives.

In such a perspective, the credibility of sustainability disclosures should not be evaluated exclusively based on the quality of reporting. Instead, the crux of the issue is fundamentally a knowledge system problem. In the event of an organisation’s foundational knowledge system being weak, the disclosures produced may be ‘complete’ but fragile. This is because metrics can vary over time, the same label

might carry different meanings, and the evidence supporting claims can be hard to trace. In such situations, stakeholders are left to interpret signals with limited ability to distinguish between genuine commitments and mere symbolic gestures. It is precisely at this juncture that greenwashing becomes a more probable occurrence, not merely as a deliberate act of deception, but also as an inevitable consequence of ambiguous standards, subjective measurement choices, and inadequate traceability (Ben Mahjoub, 2025).

The issue is rendered even more complex by two key factors. Firstly, it is important to note that the assessment of sustainability information is conducted by a variety of intermediaries, including rating agencies, analysts, NGOs, and auditors. Each of these entities employs its own unique systems for the categorisation and weighting of information. This well-known inconsistency in sustainability ratings highlights the lack of a unified taxonomy and the different approaches to measurement and aggregation. Secondly, credibility is predicated on relationships; the same piece of information can resonate with one group while failing to resonate with another, influenced by their cognitive perspectives, past experiences, and how trustworthy they find the evidence presented.

Considering these challenges, it is recommended that the conception of credible sustainability disclosure be regarded as an architectural issue (Berg et al., 2022).

3.2 Defining knowledge architecture in the sustainability domain

The term ‘knowledge architecture’ has been identified in a variety of fields, including knowledge management, information systems, and organisational design (Kaipa, 2000; Oliver et al., 2021). In the context of sustainability disclosure, the concept of knowledge architecture can be defined as a socio-technical system that builds upon a set of principles, artefacts, and routines that facilitate the definition and codification of sustainability information within an organisation. It also ensures consistent interpretation of sustainability information across different functions and disclosure channels. Furthermore, it enables translation and negotiation across knowledge boundaries while maintaining traceability between what is disclosed, the underlying data, and the responsible parties. It is important to emphasise three fundamental aspects of this definition.

Firstly, it is important to note that knowledge architecture is inherently socio-technical in nature. The term encompasses repositories and data models, but also includes standards, roles, documentation protocols, and interpretative routines. This perspective is in alignment with the field of knowledge management research, which posits that organisational knowledge is a dynamic interplay between tacit and explicit elements, influenced by social interactions and managerial design (Nonaka, 1994).

Secondly, knowledge architecture prioritises ‘meaning’ over ‘measurement’. Sustainability metrics are not merely neutral reflections of reality; they are the result of specific definitional and classificatory choices. The variation in sustainability ratings serves to underscore the assertion that classification and aggregation are not merely technical details; rather, they constitute pivotal interpretative processes (Berg et al., 2022).

Third, the role of knowledge architecture in ensuring verifiability is crucial. Disclosure faces the challenge of a lack of information: individuals external to the organization are required to evaluate the claims made by the organization, frequently without complete insight into the internal processes of the organization. As is indicated by a considerable body of literature on disclosure, the requirement for transparency is a consequence of the existence of an information gap and of conflicts of interest (Healy & Palepu, 2001). From this standpoint, a robust knowledge architecture functions as a mechanism that curtails interpretive discretion and augments the capacity of stakeholders and those assuring to comprehend the rationale and substantiation underpinning sustainability assertions.

4 Methodology

Thanks to the adoption of a deductive approach (Reyes, 2004) and a systems-thinking perspective (Barile & Saviano, 2017), this study reinterprets sustainability disclosure as not just a reporting obligation, but also as an emerging organisational design issue. Adopting a conceptual perspective (Bryman, 2016), the study provides a theoretical reflection on the vital role of knowledge architecture in sustainable governance, particularly in mitigating the risk of greenwashing and subsystem scepticism.

Central to this methodological framework is the concept of socio-technical knowledge infrastructure, which stabilises meanings, aligns interpretative schemes, and assures the traceability and verifiability of sustainability information. In other words, the methodology supports the development of an innovative interpretative perspective through which sustainability systems can be designed to reduce speculative and asymmetric behaviours, thereby increasing stakeholder trust. Furthermore, this methodological approach highlights that the credibility of sustainability disclosure emerges during the rethinking and design of complex knowledge systems, rather than after the event.

5 The conceptual path and the knowledge architecture for viable sustainability disclosure

As illustrated in the following Figure 1, the perspective shift from sustainability disclosure as a mere reporting outcome to acknowledging it as a construct of a knowledge system requires a clear and sharable path. The figure supports the idea that credibility is not something that just appears at the end of the process, when the disclosure is finally made public. Instead, the focus should be on the organisational structures that define, connect, and make the underlying sustainability-related information verifiable.

The figure illustrates this concept by depicting knowledge architecture as a configuration based on four interconnected components:

The codification standards include definitions, measurement rules, documentation protocols, and an ethics code. These elements establish boundaries on the extent of interpretive freedom, thereby enabling consistent comparisons over time.

The shared taxonomies and ontologies are built within the organisation for ensuring effectiveness of internal sustainability information processes among the multiple departments (finance, operations, human resources, procurement, ...).

The boundary objects are useful for ensuring reciprocal understanding across different stakeholders without losing the wide variety of perspectives that sustainability issues entail.

The traceability mechanisms needed to emphasize source referencing, versioning, and audit-ready repositories. The efficacy of these mechanisms is reinforced by the utilisation of stakeholder surveys, which function as a conduit for the collection of external feedback, subsequently integrated into internal knowledge processes.

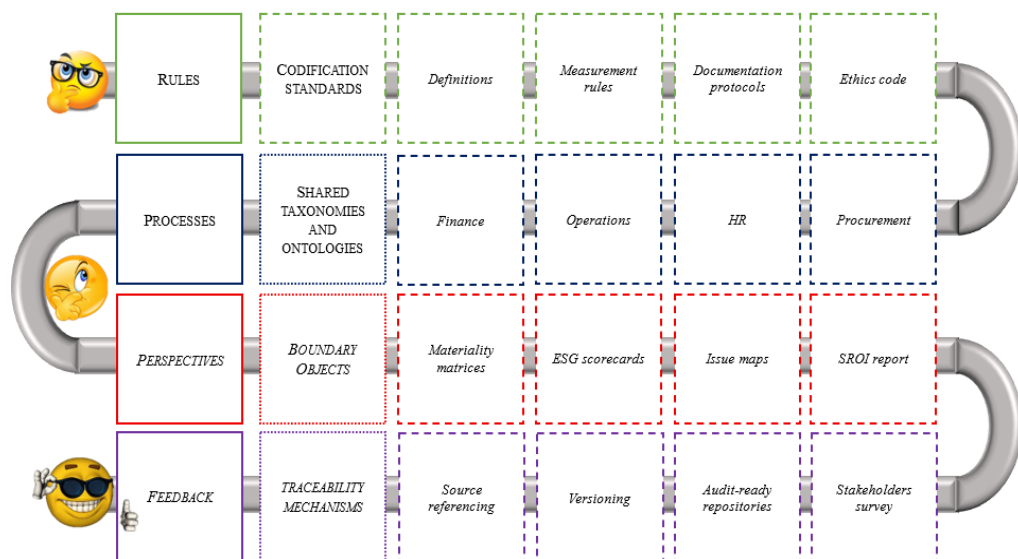


Figure 1: The conceptual path and the knowledge architecture for viable sustainability disclosure

Source: Authors' elaboration, www.asvsa.org

Figure 1 shows these building blocks not as a 'simple' checklist, but as a dynamic and multifaceted array. It proposes the establishment of a 'conceptual path' based on rules, processes, perspectives, and feedback. This configuration serves to elucidate the internal logic of the framework.

The foundation for this process is the establishment of rules that provide stability in meanings, followed by the implementation of processes that ensure organizational production and integration. The subsequent phase involves the utilization of perspectives that facilitate coordination across boundaries and is upheld by feedback that connects claims to evidence, thereby supporting learning and adjustments over time.

This interpretation is consistent with a systems-thinking view of knowledge processes, whereby the emphasis is placed not only on the possession of information but also on the conditions that enable information dissemination, comprehension, and utilisation for the development of knowledge across interconnected systems (Hoang, 2018).

In this context, Figure 1 represents an attempt to ‘design’ the conditions that enable sustainability information to flow seamlessly across functions and stakeholders without compromising its coherence. This, in turn, has the effect of minimising the discretionary space that is often the catalyst for scepticism and the risk of greenwashing.

The focus on feedback goes beyond just management; it’s rooted in theory. Recent studies that blend complex adaptive systems with sustainability as a co-created service emphasize the importance of feedback loops as vital tools for aligning the thoughts and actions of various stakeholders (Saviano et al., 2025).

Overall, Figure 1 serves two key purposes: on one hand, it illustrates that credible sustainability disclosure arises from the arrangement of foundational elements, not just from the effort put into reporting; on the other hand, it sets the stage to clarify how interpretive flexibility can be minimized while enhancing coherence and verifiability.

6 Implications for sustainable governance and management

If the credibility of sustainability disclosure depends on knowledge architecture, then sustainability governance cannot consist only of the oversight of reporting outputs alone. Instead, it ought to extend to the design and continuous refinement of the organizational infrastructures of sustainability knowledge (Robinson et al., 2006).

Moreover, the responsibility for knowledge integrity cannot remain confined to a single function and requires clarifying roles within firms. The proposed framework implies that transparency is not achieved *ex post*, but *ex ante* through architectural design choices that constrain interpretative discretion and strengthen verifiability. More specifically, the four components of knowledge architecture can be transformed into actionable governance principles.

First, codification standards need to be formalised. Governance bodies ought to make sure that sustainability-related definitions, rules, and protocols are explicitly codified and aligned with recognised reporting standards. Rather than delegating these decisions entirely to sustainability teams, boards and committees should directly treat sustainability codification as a strategic design issue of its own, analogous to, say, financial reporting policies. As shown in established Knowledge Management research, formal codification strategies do indeed enhance organizational coherence by facilitating controlled knowledge flows (Hansen et al., 1999; Alavi & Leidner, 2001).

Second, shared taxonomies and ontologies need to be embedded across functions. To reduce semantic fragmentation across departments and foster coherence and alignment, executive leadership must prevent the sustainability of information from becoming soiled within isolated departments, legitimizing cross-functional alignment mechanisms. These may include shared reporting templates and interdepartmental working groups or any channels to ensure common meanings (Ubbiali et al., 2026). Executive management should sponsor cross-functional integration and give resources to harmonize taxonomies.

Third, boundary objects should be deliberately designed and periodically recalibrated. In other words, boundary objects ought to be conceived as governance instruments that mediate between strategic intent and operational reality. Hence, governance bodies should first treat sustainability scorecards as shared formats, periodically recalibrated to prevent detachment from evolving sustainability priorities. The role of sustainability scorecards can be understood through the lens of boundary object theory, whereby shared artefacts enable coordination across heterogeneous domains without requiring full consensus on given assumptions (Star & Griesemer, 1989). Operational managers must ensure that data generation processes are consistent with codified standards, while internal audit and compliance functions can periodically assess architectural coherence.

Fourth, traceability mechanisms must comprise an established chain of evidence. Sustainable governance requires that every sustainability disclosure be linked to identifiable sources of data and methodologies. Clear attribution of accountability, along with structured repositories to strengthen traceability, may reduce the risk of narratives that outpace underlying evidence. Strengthening traceability mechanisms

aligns with broader literature insights that highlight that credible disclosure depends on verifiable evidence chains (Power, 1997; Simnett et al., 2009).

For example, sustainability disclosure in fashion systems represents a complex and multidimensional challenge that goes beyond mere technical compliance with regulatory requirements. The growing intricacy of global supply chains exacerbates the critical issues associated with sustainability disclosure, exposing it to information fragmentation and interpretative flexibility (Bassano et al., 2020). In a context where the perceptions and expectations of customers play a crucial role, sustainability is increasingly being reinterpreted as a design choice that emerges from interactions between multiple actors, functions, and organisational levels (Amendola et al., 2018). Organisational entities are therefore rethinking knowledge architectures that are not only grounded in measurement rules, documentation protocols, and ethical codes, but also in shared taxonomies that enhance the effectiveness of internal information processes. These configurations are further enabled by the adoption of materiality matrices and scorecards, which facilitate coordination across different domains without imposing excessive rigidity. At the same time, introducing traceability mechanisms along the entire supply chain enables consistency to be verified between sustainability narratives and underlying operational practices.

Another pioneering example lies in healthcare systems, where the codification of sustainability-related information is particularly articulated (Barile et al., 2014). This stems from data fragmentation and heterogeneity, the multitude of entities involved, and the lack of shared standards for collecting and interpreting the evolutionary pathway from data to information to sustainability knowledge (Polese et al., 2018; Saviano et al., 2019). For these reasons, healthcare organisations are increasingly designing the necessary conditions in terms of standards, roles, and protocols that enable sustainability information to be credible. This considers not only the quantitative dimension of measurement, but also the construction and sharing of 'meaning'. In other words, the healthcare sector is gradually reshaping its existing knowledge infrastructures to minimise ambiguity in clinical data interpretation, promote alignment across departments, reduce the cognitive distance between professionals and patients, and identify new ways to integrate external feedback (Caputo & Cervino, 2025).

In summary, to translate these principles into practice, organizations may follow a variety of pathways. Diagnostic assessments can map initial existing sustainability knowledge flows, identifying fragmentation points, definitional inconsistencies, and weak traceability links. Based on the resulting diagnosis, architectural interventions should be designed to stabilise core definitions and progressively align taxonomies across functions. As prior research on greenwashing shows, selective disclosure is indeed more likely to emerge in contexts where monitoring is limited, and internal structures fail to constrain discretionary representation (Lyon & Montgomery, 2015). Via regular reviews, along with stakeholder feedback mechanisms, organizations can monitor knowledge architecture over time. In sum, by embedding codification standards, shared taxonomies, boundary objects, and traceability mechanisms into governance routines, organizations can transform sustainability reporting into a credible, verifiable, and transparent knowledge architecture.

7 Conclusions and research agenda

This study highlights the crucial role of knowledge architecture in ensuring credible sustainability disclosure and mitigating greenwashing risk. Moving beyond a reductionist understanding of sustainability reporting as a mere measurement, the chapter identifies sustainability disclosure credibility as an architectural design problem. In line with prior contributions that emphasize the systems nature of knowledge processes and organizational viability (Barile & Saviano, 2017; Caputo, 2017), the work shows that the reliability, coherence, and verifiability of sustainability claims depend on the organizational systems that govern, codify, and trace sustainability knowledge. The central argument advanced in this conceptual study is that greenwashing risk does not arise solely from deliberate opportunism but also from architectural fragility such as weak codification standards, fragmented taxonomies, poorly designed boundary objects, and inefficient traceability mechanisms. In a context characterized by informational variety, organizational systems that fail to stabilize meanings and constrain discretionary interpretation expose firms to dissonances, stakeholders' skepticism, and signaling distortions. Hence, sustainability credibility emerges not from the quantity of information disclosed but from the capability of organizations to create consonance among data, interpretative schemes, and value categories (Caputo & Evangelista, 2018).

From a theoretical advancement perspective, the contribution demonstrates how organizational design choices, such as codification standards, shared taxonomies,

boundary objects, and traceability mechanisms, can reduce interpretive discretion, enhance informational alignment, and strengthen stakeholder trust.

The chapter contributes to literature in three main ways. First, it extends the debate on sustainability disclosure and information asymmetry (Spence, 1978; Healy & Palepu, 2001), by arguing that the credibility and effectiveness of disclosure depend on the structural robustness of the underlying knowledge system. Second, it contributes to knowledge management research by arguing that knowledge architecture is a governance lever useful for managing variety in complex sustainability contexts (Caputo et al., 2021). Third, it furthers greenwashing research (Delmas & Burbano, 2011) by decoding an architectural explanation for selective disclosure and interpretative drift.

Moreover, the conceptual model provides operational guidance for managers seeking to enhance the transparency and credibility of reporting systems, prevent selective communication, and reduce informational and cognitive dissonances. For policymakers, the study offers practical support for rethinking policies and regulatory interventions aimed at restoring a holistic perspective on the creation and dissemination of sustainability knowledge.

Despite its contributions to existing literature, this study has limitations that affect its interpretative and practical effectiveness. Firstly, the work is based purely on a conceptual approach and is not supported by empirical evidence. The proposed framework is a preliminary attempt to systematise knowledge architecture in the sustainability domain, but has not been validated.

Secondly, there is a lack of measurement instruments capable of operationalising the model's dimensions and empirically 'testing' the relationships between the components of the knowledge architecture and organisations' ability to connect, integrate, and disclose credible sustainability information. Consequently, the study is characterised by a high level of theoretical abstraction. While this enhances its generalisability, it also constrains its immediate practical applicability. Finally, the conceptual model does not explicitly consider contextual variability. Different sectors, institutional contexts, and levels of organisational maturity may significantly influence the configuration of the knowledge architecture and its effect on sustainability disclosure.

Overall, these limitations highlight that the study is only the first step in a broader research agenda aimed at understanding how to rethink, design, and build organisational infrastructures that enable sustainability information to be verified and reliable.

Looking to the future, the first research line, in fact, requires the operationalization of knowledge architecture in the sustainability field. Future studies may design measurement approaches that capture the robustness of sustainability knowledge systems along the four proposed dimensions (codification standards, shared taxonomies, boundary objects, and traceability mechanisms). A second empirical pathway concerns datasets that capture the cross-functional nature of sustainability information (Saviano et al., 2019). Researchers may combine sustainability reports with other data to examine whether architectural configurations that are stronger correlate with greater consistency across disclosure channels. Another possible research pathway consists of deepening the understanding of the functioning and evolution of knowledge architecture via comparative case studies across industries or process-oriented analyses. Moreover, cross-country projects could also assess the contextual validity of the proposed framework, as well as provide further refinement to the approach.

Briefly, this chapter suggests that sustainable governance requires architectural intentionality and that transparency is achieved ex-ante, through the design of systems that stabilize meaning, align interpretations, and preserve verifiability. Knowledge architecture is argued to be a structural condition of credible sustainability disclosure. The study, hence, invites scholars to move beyond reporting analyses and practitioners to design infrastructures that may support coherent, transparent, accountable sustainability claims. Ultimately, it is possible to state that credible sustainability disclosure is not simply reported: it is architected for ensuring viability.

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GENDER EQUALITY AND ITS SPILL OVER EFFECTS ON EDUCATION, EMPLOYMENT, AND INSTITUTIONS WITHIN SUSTAINABLE DEVELOPMENT: AN INDIAN PERSPECTIVE

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As the world approaches the 2030 deadline for the Sustainable Development Goals (SDGs), gender equality remains essential for inclusive and sustainable growth. No country can progress socially or economically without ensuring equal opportunities for women and men. India, with its vast and diverse population, plays a key role in achieving SDG 5 globally. Despite multiple policy initiatives, significant gender disparities persist across states, affecting education, employment, and institutional effectiveness. This study evaluates India's progress toward gender equality by analysing SDG 5 and its linkages with SDGs 4 (Quality Education), 8 (Decent Work), and 16 (Peace and Justice). Using SDG indicators and text analytics of government schemes and reports, the research applies clustering, network analysis, topic modelling, sentiment analysis, and N-gram mapping across 28 states and 8 Union Territories from 2018 to 2024. Findings highlight key indicators such as sex ratio at birth, female labour force participation, and pupil-teacher ratios as critical drivers of development. While some states show steady progress, others face persistent structural challenges. The study further integrates ESG dimensions and provides actionable policy recommendations to enhance gender-responsive development.

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1 Introduction

The Sustainable Development Goals (SDGs) provide a comprehensive global framework aimed at achieving inclusive and sustainable development by 2030. Among these goals, gender equality (SDG 5) holds a pivotal position due to its strong interconnections with education, economic development, and institutional governance. India's performance is particularly significant in this context, as it represents a substantial proportion of the global population and exhibits wide socio-economic diversity across its states. The achievement of SDG targets in India will therefore have a profound impact on global development outcomes.

Gender equality is also a central component of Environmental, Social, and Governance (ESG) frameworks, particularly within the social and governance dimensions. Ensuring equitable access to education, employment, and decision-making opportunities contributes not only to social justice but also to economic productivity and institutional effectiveness. Inclusive governance structures and gender-diverse leadership are increasingly recognized as essential for sustainable development.

Despite several national-level initiatives such as Beti Bachao Beti Padhao, Skill India, and various women empowerment programs, disparities persist across Indian states in key indicators such as education, labour force participation, and institutional representation. These variations highlight the importance of conducting state-level analysis to identify region-specific challenges and policy gaps. This study therefore examines the interlinkages between gender equality and key development outcomes by integrating quantitative SDG indicators with qualitative policy analysis, offering a comprehensive and data-driven perspective.

2 Review of Literature

Gender equality has been widely acknowledged as a critical determinant of economic and social development. Duflo (2012) emphasizes the bidirectional relationship between gender equality and economic growth, arguing that improvements in one reinforce the other. Sen's (1999) capability approach further highlights that expanding women's access to education, employment, and decision-making enhances overall societal well-being and development outcomes.

In the Indian context, Sahni (2024) identifies significant disparities in gender indicators across states, emphasizing the need for targeted interventions. Chatterjee (2021) highlights the role of governance and institutional capacity in influencing SDG performance, while Tamuli and Mishra (2023) focus on women's empowerment through education, skill development, and labour participation. Asadullah et al. (2024) point out the disconnect between educational attainment and employment outcomes, particularly in developing economies, which limits the effectiveness of gender-focused policies.

From an ESG perspective, gender equality is increasingly recognized as a key component of sustainable development. Reports by the World Bank (2023), UN Women (2022), and OECD (2021) indicate that gender inclusion enhances productivity, strengthens governance, and contributes to long-term sustainability. However, existing literature is limited by its reliance on structured indicators, lack of integration between SDGs, and limited use of advanced analytical techniques. This study addresses these gaps by adopting an integrated analytical framework combining quantitative and qualitative approaches.

3 Theoretical Framework

This study develops a Gender-SDG-ESG Integrated Analytical Framework that conceptualizes gender equality as a systemic driver of sustainable development. Unlike existing approaches that treat SDGs as independent goals, this framework positions gender equality as a central variable generating spillover effects across education, employment, and institutional governance.

The framework is grounded in three theoretical perspectives. The capability approach emphasizes that expanding women's access to resources and opportunities enhances human development. Human capital theory highlights the role of education and skill development in improving productivity and economic outcomes. Institutional theory underscores the importance of governance structures and policies in shaping gender equality outcomes.

The framework identifies three key pathways through which gender equality influences development. The first pathway operates through education, where improved access to education enhances human capital and long-term productivity.

The second pathway operates through labour markets, where increased female participation contributes to economic growth and income equality. The third pathway operates through institutions, where greater representation of women improves governance quality, transparency, and accountability. These pathways are further embedded within ESG dimensions, where gender equality strengthens both social inclusion and governance effectiveness, making it a critical component of sustainable development strategies.

4 Methodology

This study adopts a mixed-methods approach integrating quantitative SDG indicators with qualitative policy text analysis. Structured data were obtained from the NITI Aayog SDG India Index (2018–2024), along with supplementary datasets from the World Bank and UNDP. Unstructured data were collected from government policy documents, scheme reports, and official publications related to gender equality, education, labour, and governance.

The quantitative analysis employs K-means clustering to classify states based on SDG performance indicators. The optimal number of clusters was determined using the Elbow Method and validated through Silhouette Scores to ensure robustness. Network analysis was conducted to examine relationships among SDG indicators, using degree and betweenness centrality measures to identify key variables acting as connectors between SDGs.

Qualitative analysis was conducted using natural language processing techniques. Topic modelling was performed using Latent Dirichlet Allocation, with coherence scores used to determine the optimal number of topics. Sentiment analysis was conducted using the VADER lexicon to assess the tone of policy documents, while N-gram analysis was used to identify recurring themes and policy priorities.

The study follows a hierarchical analytical structure, beginning with descriptive analysis to identify trends, followed by clustering to group states, network analysis to explore interdependencies, and text analytics to interpret policy narratives. This structured approach ensures coherence and allows each method to complement the others.

To ensure validity, clustering results were tested through multiple iterations, network relationships were examined for robustness, and topic models were validated using coherence scores. Despite these measures, the study has certain limitations. It relies primarily on secondary data, which may not fully capture ground-level realities. Policy documents may reflect institutional biases, and natural language processing techniques may not fully capture contextual nuances. Additionally, the absence of primary data such as interviews or surveys limits the empirical depth of the analysis. Future research can address these limitations by incorporating field-based data and stakeholder perspectives.

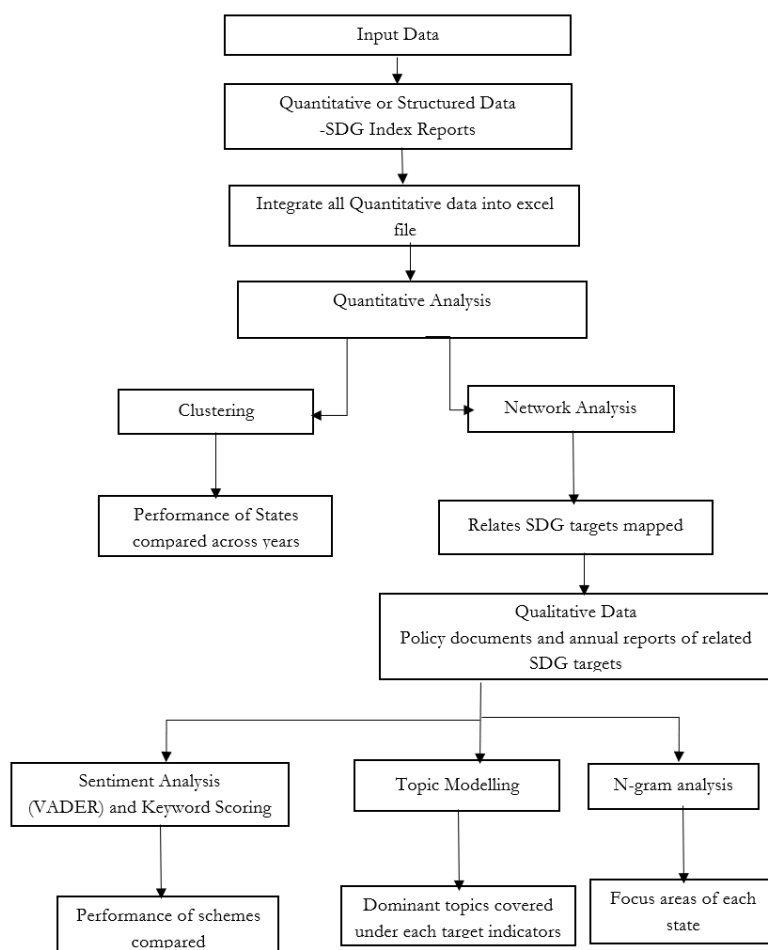


Figure 1: Research Design

The findings reveal that key indicators such as female labour force participation, sex ratio at birth, and pupil–teacher ratios serve as critical connectors linking gender equality with education, employment, and institutional outcomes. Network analysis demonstrates that these indicators function as bridging variables across SDGs, highlighting the interconnected nature of development.

Clustering results indicate significant regional disparities. Southern states and certain hill regions consistently perform better due to stronger educational systems, progressive policies, and effective governance. In contrast, several northern and eastern states face structural challenges related to socio-cultural norms and institutional capacity. The COVID-19 pandemic further widened these disparities, although partial recovery has been observed in subsequent years.

Text analytics reveals that policy focus is concentrated on labour welfare, women's safety, and digital education initiatives. However, relatively less emphasis is placed on financial inclusion and institutional reforms, indicating potential gaps in policy priorities. Sentiment analysis suggests that policies related to education and employment are more action-oriented, whereas governance-related policies tend to be more descriptive. These findings highlight the need for improved policy implementation and monitoring mechanisms.

Sentiment patterns further reveal that education and labour schemes employ more action-oriented and implementation-focused language compared to welfare and judicial reform programmes. This indicates that policies related to education and employment are framed with clearer operational intent, measurable targets, and a stronger emphasis on outcomes such as skill development, job creation, and workforce participation. In contrast, welfare and judicial reform programmes tend to adopt more descriptive and normative language, focusing on rights, protection, and long-term institutional goals rather than immediate execution. This divergence suggests a potential imbalance in policy prioritization, where sectors directly linked to economic productivity receive more concrete and actionable planning, while governance and justice-related areas remain less operationalized. Such patterns may affect the effectiveness of institutional reforms, as the absence of clearly defined implementation mechanisms can limit policy impact. Strengthening the actionability of governance-related policies through measurable targets, accountability

frameworks, and periodic evaluation mechanisms could enhance their contribution to overall development outcomes and improve alignment across SDGs.

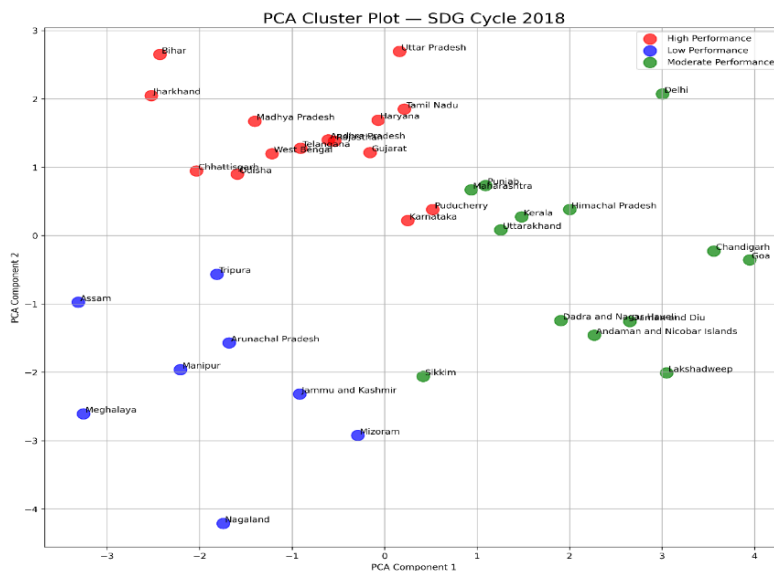


Figure 2: SDG Cycle 2018

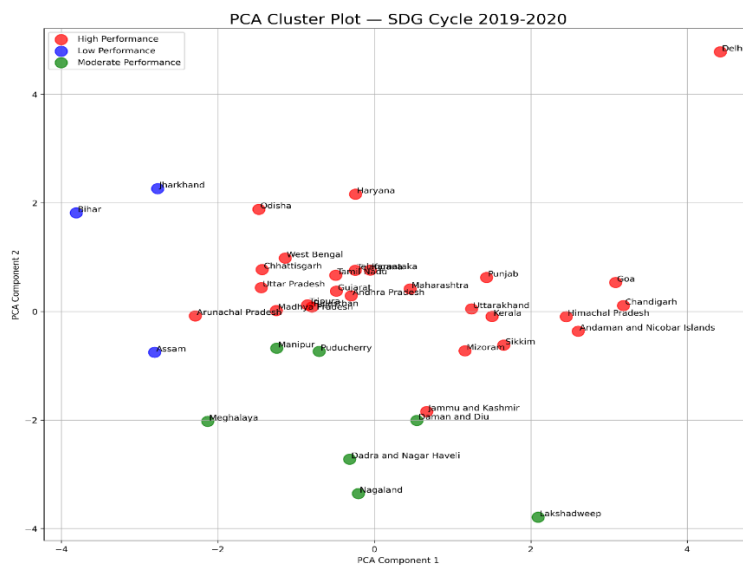


Figure 3: SDG Cycle 2019-2020

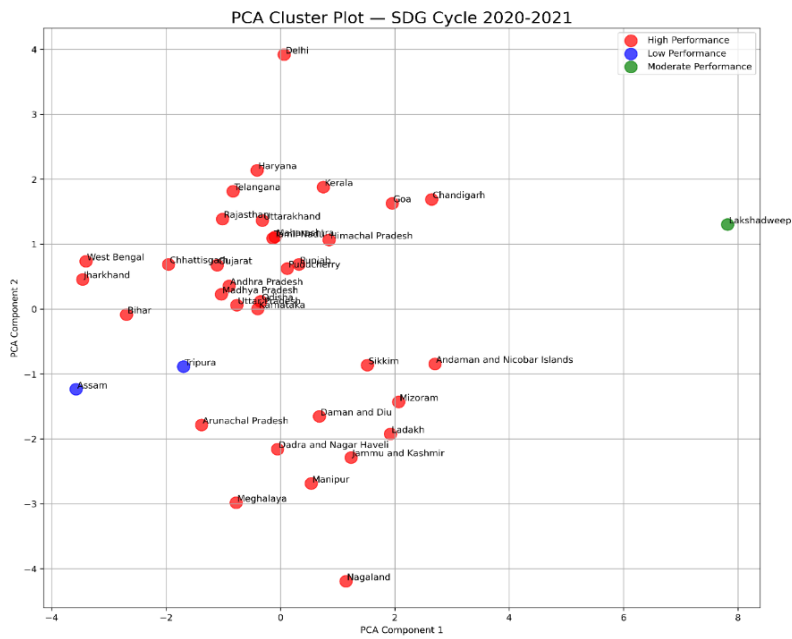


Figure 4: SDG Cycle 2020-2021

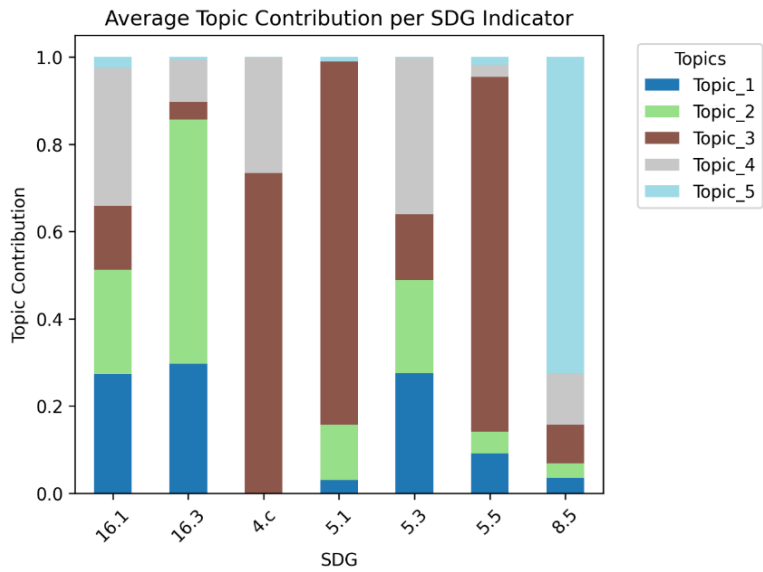


Figure 5: Average topic Contribution

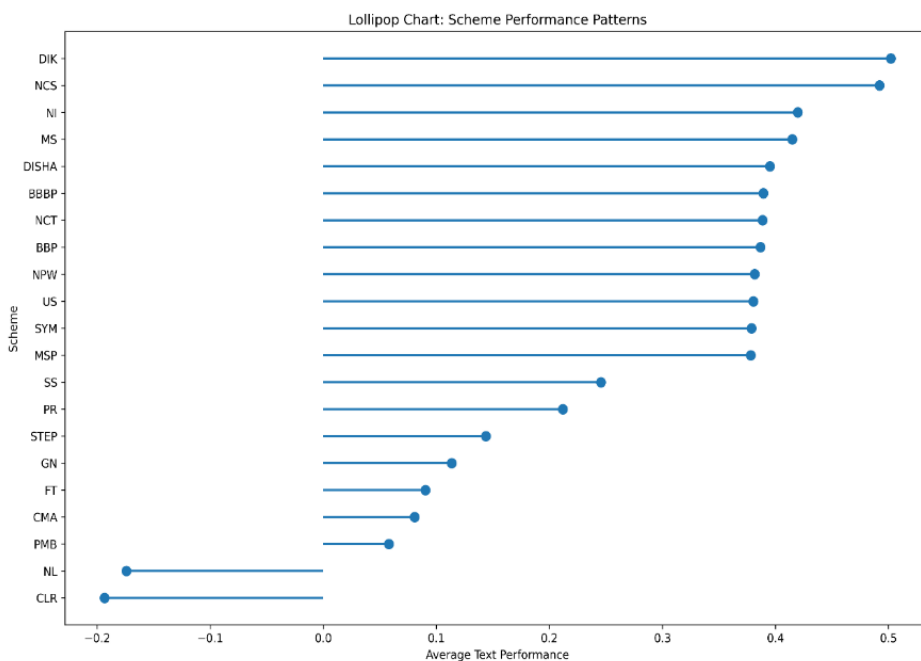


Figure 6: Scheme Performance Patterns

The scheme performance patterns illustrated in Figure 6 reveal significant variations in the effectiveness and orientation of gender-related policies across states and sectors. The analysis indicates that schemes linked to education and labour tend to demonstrate relatively stronger performance outcomes, reflecting better alignment between policy design and implementation mechanisms. These schemes often incorporate clearly defined targets, measurable indicators, and structured delivery frameworks, which contribute to more tangible improvements in female participation in education and the workforce.

In contrast, schemes related to welfare and judicial reforms exhibit comparatively moderate or inconsistent performance patterns. This can be attributed to their broader and often less quantifiable objectives, such as social protection, legal awareness, and institutional strengthening. The absence of clearly defined performance metrics and monitoring mechanisms in these areas may limit their effectiveness and reduce their ability to generate immediate, observable outcomes.

The variation in scheme performance also highlights the role of state capacity, governance quality, and socio-economic conditions in determining policy effectiveness. States with stronger administrative systems, higher levels of human development, and better institutional coordination tend to achieve more consistent results across multiple schemes. Conversely, states facing structural challenges such as resource constraints, socio-cultural barriers, and weaker governance frameworks show slower progress and uneven outcomes.

Furthermore, the analysis suggests that policy coherence and inter-sectoral coordination are critical in maximizing the impact of gender-focused interventions. Schemes that are integrated across education, employment, and governance domains tend to produce stronger spillover effects, reinforcing the interconnected nature of SDGs. The findings therefore emphasize that gender equality is not an isolated objective but a cross-cutting factor that influences broader development outcomes. Strengthening implementation mechanisms, improving monitoring systems, and enhancing coordination across sectors can significantly improve the overall effectiveness of gender-related schemes and accelerate progress toward multiple SDG targets.

6 Gender Equality within ESG Framework

Gender equality plays a crucial role within ESG frameworks, particularly in the social and governance dimensions. From a social perspective, it promotes inclusion, equity, and access to opportunities, contributing to human capital development and economic growth. From a governance perspective, gender diversity in leadership enhances institutional transparency, accountability, and decision-making effectiveness. Women also play an important role in environmental sustainability, particularly in resource management and climate adaptation.

Integrating gender equality into ESG frameworks provides a holistic approach to sustainable development. Aligning SDG and ESG objectives can enhance policy effectiveness, improve governance outcomes, and support long-term sustainability.

7 Policy Recommendations

The findings of this study suggest the need for targeted and actionable policy interventions. Policymakers should adopt a differentiated approach by prioritizing interventions based on state-specific performance levels. Low-performing states should focus on improving education access, labour market opportunities, and institutional capacity, while high-performing states should focus on sustaining progress through innovation and governance reforms.

Efforts to increase female labour force participation should include targeted skill development programs aligned with industry needs, incentives for employers, and improvements in workplace safety and childcare infrastructure. Education policies should prioritize reducing dropout rates among girls, improving infrastructure, and promoting digital learning. Governance reforms should focus on increasing women's representation in decision-making roles and strengthening institutional mechanisms. Financial inclusion initiatives should expand access to credit and support women-led enterprises. Integrating ESG principles into policy frameworks can further enhance the effectiveness of these interventions.

8 Conclusion

This study demonstrates that gender equality is a fundamental driver of sustainable development in India. By influencing education, employment, and institutional outcomes, it generates significant spillover effects across multiple SDGs. While progress has been made, persistent disparities highlight the need for targeted and context-specific policies. Integrating ESG frameworks with SDG strategies can further strengthen development outcomes. A comprehensive, gender-responsive approach will be essential for achieving inclusive and sustainable growth by 2030.

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End notes

The SDG indicators used in this study are primarily derived from the NITI Aayog SDG India Index (2018–2024) along with supplementary datasets from the United Nations Development Programme and the World Bank. Text analytics was conducted using Python-based libraries including Scikit-learn and natural language processing techniques such as topic modelling and sentiment analysis.

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Summary

This study analyses the role of gender equality in advancing sustainable development in India by examining its connections with education, employment, and institutional effectiveness. Using SDG indicator data from NITI Aayog, along with datasets from the United Nations Development Programme and the World Bank, the research evaluates state-wise progress between 2018 and 2024.

Analytical techniques including clustering, network analysis, and natural language processing are applied to identify relationships among SDG 5, SDG 4, SDG 8, and SDG 16. The findings highlight key indicators influencing development outcomes and reveal regional disparities, emphasizing the importance of gender-responsive and context-specific policy interventions.

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AN EXAMINATION OF THE CHALLENGES ASSOCIATED WITH OLFACTORY STIMULI IN MUSEUM SERVICES: A SYSTEMATIC REVIEW OF VISITOR-CENTRIC STRATEGIES

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This systematic review examines the impact of olfactory stimuli in museums, revealing a gap in the literature on how scents enhance visitor experiences. Utilising the PRISMA methodology, we analysed 237 records from various academic databases. Findings illustrate that scents are often thematically aligned with exhibits, such as historical scents, to deepen visitor engagement. Art galleries also utilise scents to enhance emotional and cognitive responses, evoking memories and enhancing immersion. Both pleasant and unpleasant scents impact visitors: pleasant scents improve mood and engagement, while unpleasant scents can intensify emotional reactions and immersion. Nevertheless, challenges like olfactory fatigue and technical limitations in scent delivery can hinder effectiveness. Overuse or weak diffusion may detract from the intended experience. Multisensory approaches that combine scent with other stimuli are especially beneficial for inclusivity, particularly for visually impaired visitors. Yet the review also identifies methodological limitations in current research, including small sample sizes, limited demographic diversity, and laboratory-based settings. The absence of standardised guidelines makes consistent integration difficult. Overall, this review highlights the potential of olfactory elements to enrich museum experiences and encourages further exploration and innovation in integrating olfactory stimuli into cultural experiences, including via a customer-centric lens.

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1 Introduction

Museums in the 21st century stand as cornerstones of cultural and intellectual knowledge, experience and heritage. And while many of their primary functions remain unchanged (collecting, caring for, and displaying works of art and artefacts), contemporary challenges have shifted the way museums are managed and the goals they pursue.

Museums aspire to become more visitor-focused (Roederer & Filser, 2018). Their evolution has led them from being primarily collections-based to more education-focused places (McGinnis, 2014) or, as Weil (2002, 28) put it, “from being about something to being for somebody.” This new way of thinking has pushed them toward delivering sociable, recreational, and participatory experiences (Kotler, 2001), which extend beyond traditional visual-centric museum displays to multisensory exhibits.

Most of the world-famous museums, and a plethora of smaller ones, have adopted exhibits that encourage visitors to experience the displays not only by seeing, but also through audio, tactile, proprioceptive, and olfactory stimuli, with some success. Several studies have demonstrated the positive effects of multisensory exhibitions on visitors’ engagement, stimulation (Jung et al., 2019), recall (Aggleton & Waskett, 1999), and general experience (Keller, 2014).

However, olfactory stimuli are often overlooked in a museum context (Drobnick, 2004; Stevenson, 2014). While there are some exceptions, museums tend to provide a rather clinical environment where smells and odours are generally unwelcome (Verbeek et al., 2022), as these stimuli are hard to define, distribute, control, and recreate (Spence, 2020). Verbeek et al. (2022) also noted a notable lack of both descriptive and evaluative research on the topic. They have advocated for “more research-oriented approaches, capturing the development and impact of sensory approaches within the heritage contexts” (Verbeek et al., 2022, 317).

The limited number of studies from the museology of smell, as well as from other fields (e.g. marketing), show that scents positively impact museum visitors, by raising engagement, memorability, increasing the time spent viewing displays, lowering museum fatigue, enhancing the affective impact, and understanding of the art

(Aggleton & Waskett, 1999; Keller, 2014; Mitchell et al., 1995; Spence, 2020; Vega-Gómez et al., 2020; Verbeek et al., 2022; Vi et al., 2017).

In general, there are two main propositions on how olfactory stimuli may influence our mood, physiology, and behaviour: pharmacological and psychological hypotheses. The pharmacological hypothesis states that aromas' effects are due to their direct ability to interact with and affect the nervous and endocrine systems. On the other hand, the psychological hypothesis promotes an indirect effect, stating that "responses to odours are learned through association with emotional experiences, and that odours consequently take on the properties of the associated emotions and exert the concordant emotional, cognitive, behavioural and physiological effects themselves" (Herz, 2009, 276). Spence et al. (2014) note two additional characteristics of olfactory stimuli. Firstly, the authors note that responses to olfactory cues are more likely to be hedonically charged than responses to other stimuli. Such positive or negative evaluations can induce approach or avoidance behaviours, respectively. Furthermore, the authors emphasise that scent memory is considered the strongest of the senses (Goldman & Seamon, 1992), which can inadvertently enhance the memorability of exhibitions in museums.

Despite general agreement on the benefits of "scented museums", the available literature indicates a lack of research on the use of odour in the museum context. Works that address the multisensory exhibits in museums and galleries mention olfactory stimuli briefly, as a potential sense to address in the future (e.g. Candlin, 2003; Carulli & Bordegoni, 2019; Falvo, 2012; Harada et al., 2018) or (un)intentionally ignore them altogether (e.g. Djousouf et al., 2023; Eardley et al., 2016; Smith, 2020). Again, some exceptions should be noted. The seminal paper by Spence (2020) reviews some of the challenges of using ambient scent in art galleries and museums, while Verbeek and colleagues (2022) provide an insightful report on the development of scented guided tours at the Rijksmuseum (Amsterdam). They emphasise that "conducting scented tours and curating scented displays can certainly benefit from more experiments, from better documentation and a more robust system for impact evaluation" (Verbeek et al., 2022, 336).

Our study aims to address this proposition by conducting a systematic review of published articles, gathering insights from past research through a thematic analysis, and developing guidelines for both museum staff on the development and

positioning of olfactory displays and for researchers investigating the impact of odour in the museum context. Finally, given the overall shift toward customer-centricity in museums (Kotler et al., 2008), we also propose a more customer-centric approach to visitor research. To our knowledge, there are no systematic reviews that focus solely on olfactory stimuli in museum contexts. Accordingly, this work may advance interdisciplinary research and enable new practical applications in the field.

Thus, this study contributes to the literature in three ways. First, it provides a systematic synthesis of research on olfactory stimuli in museum and gallery contexts. Second, it organises the fragmented evidence into key themes concerning visitor engagement, memory, congruence, accessibility, implementation challenges, and methodological limitations. Finally, it extends the discussion by proposing a customer-centred research agenda that connects olfactory museum experiences with perceived quality, perceived value, and visitor satisfaction.

2 Materials and Methods

The literature review followed the PRISMA method to develop a systematic review. This ensured transparent and comprehensive reporting of the topics surveyed. The review focused on a randomised search exploring the use of scent to enhance the museum experience, aiming to provide relevant data on its implementation, use, and evaluation. The inclusion criteria are specified in Table 1, while the exclusion criteria are outlined in Table 2.

Table 1: Inclusion criteria

Inclusion criteria	Description
Inclusion criterion 1	The paper has one of the following terms in the title, abstract, or keywords: 'scent', 'odour', 'olfactory', 'smell' or 'multisensory'; along with one of the terms: 'museum' or 'gallery'; and with one of the terms: 'visitor', 'consumer', 'participant' or 'tourist'; And with one of the terms: 'perception', 'experience' or 'attitude'
Inclusion criterion 2	The paper is written in English or Slovenian.
Inclusion criterion 3	We have access to the full text of the paper.

To conduct a comprehensive survey on the specified topics, two search stages were employed: an online search and an analysis of the records obtained from the initial search.

For the first stage, literature was identified through extensive searches of well-known databases, including Web of Science, Elsevier Scopus, and EBSCO. The search was initiated in July 2024 and used the logical expression: Title/Keywords/Abstract containing ('scent' OR 'odour' OR 'olfactory' OR 'smell' OR 'multisensory') AND ('museum' OR 'gallery') AND ('visitor' OR 'consumer' OR 'participant' OR 'tourist') AND ('perception' OR 'experience' OR 'attitude').

During the second stage of the search process, which involves reviewing full-text articles (refer to Fig. 1 for a detailed overview of the steps outlined in the PRISMA method), a search was conducted to determine eligibility for analysis. This was necessary because certain articles lacked sufficient information for either qualitative or quantitative analysis.

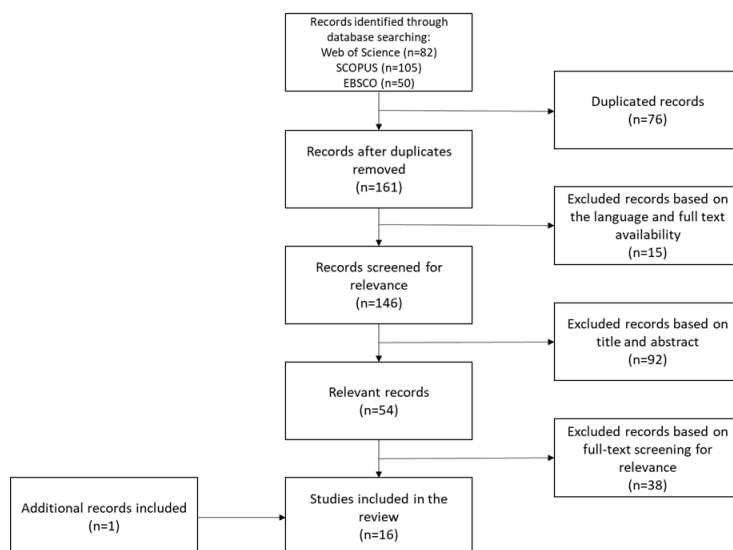


Figure 1: Detailed overview of the steps according to the PRISMA method

Source: own.

2.1 Study Selection

A total of 161 records were obtained and reviewed by two reviewers to determine their eligibility based on language and full-text availability, in line with the exclusion criteria. During this process, 6 records were discarded due to language restrictions, and 9 records were excluded because full texts could not be obtained. After reviewing the titles and abstracts of each study and applying the exclusion criteria, 92 records were excluded, leaving 54 full-text papers for eligibility assessment.

Table 2: Exclusion criteria

Exclusion criteria	Description
Exclusion criterion 1	Full-text paper is not available.
Exclusion criterion 2	The paper is written in a language other than English or Slovene.
Exclusion criterion 3	The paper does not consider the use of scent.
Exclusion criterion 4	The scent described in the paper is not applied in a museum context.

The eligibility assessment was conducted on 54 full-text papers to gather all necessary data for the current systematic review. During this process, 38 articles were excluded based on the established criteria, and the remaining articles were included from the second stage of the search. Seventeen papers were ultimately selected for full-text assessment. The variables considered included the stimuli used in the study, sample size, country, study objectives, research methods, key findings, suggestions for future research, and identified limitations.

3 Results

The search of the identified databases resulted in a total of 237 records. 76 duplicates were removed, leaving 161 unique records to be screened. The language, full-text availability, title, and abstract of these unique records were analysed against the eligibility criteria. 107 records did not meet the criteria and were excluded. This left 54 records eligible for full-text analysis. Of these, 38 records were excluded based on our predefined criteria. Subsequently, an updated search revealed 1 additional article, bringing the total number of records for qualitative synthesis to 17. Table 3 provides an overview of the key features of the included studies, including author, year, country, research design, sample characteristics, methods used, and whether and how scent was incorporated.

Table 3: Summaries of Analysed Studies

Author	Year	Type of paper	n	Methods	Smell	Device
Aggleton & Waskett	1999	Experimental	45	Questionnaire	Yes	Scents were dispersed throughout the exhibition.
Cirrincone et al.	2014	Empirical	86	Between-participant experiment	Yes	The scents were diffused during the experiment via professional diffusers.
Chu et al.	2016	Case study	13	Semi-structured interview	Multisensory	Applied to wooden disks placed inside the prototype.
Miotto	2016	Case study	-	-	Yes	Olfactory delivery device, releasing the scent on demand.
Huang et al.	2018	Empirical	32	Questionnaire, user observation and video analysis	Multisensory	2018
Carulli & Bor-degoni	2019	Case study	-	-	Multisensory	Olfactory display device that delivers odours, enabled by AR.
Wilson et al.	2020	Empirical	21	Semi-structured interviews and observations	Multisensory	-
Wang	2020	Empirical	S1 2152 S2 148	In-depth interviews, observation, questionnaires	Multisensory	Odor generator
Vega-Gómez et al.	2020	Empirical	234	Experiment, questionnaires, interviews	Yes	Device dispersing 30 s of scent every 180 s.

Author	Year	Type of paper	n	Methods	Smell	Device
Spence	2020	Review	-	-	Yes	-
Cho	2021	Review	-	-	Multisensory	-
Marto et al.	2022	Review	-	-	Multisensory	-
Vaz et al.	2017	Empirical	25	Questionnaires, observations and semi-structured interviews	Multisensory	Bowls containing spices and incense.
Verbeek et al.	2022	Empirical	S1 148 S2 60 S3 4	Questionnaires, interviews, observation	Yes	Scent-containing vases with a pump, Aroma-Jockey, ultrasonic scent diffusers, blotters, headspace (dry diffusion) techniques, whispies.
Blundell	2023	Case study	3	Interview	Smell and taste	Motion-activated diffusers, scent-dispensing foot pump and AirParfum.
Zhang et al.	2023	Empirical	12	Experiment, post-study interviews, questionnaires	Yes	Olfactory display – controlled odour release.
Luo et al.	2024	Review	-	-	Multisensory	-

3.1. Overview of Analysed Studies

Our review includes 17 articles: 4 case studies, 4 review articles, and 9 empirical studies. The studies varied considerably in their research design, empirical setting, and treatment of olfactory stimuli. 9 articles focus on multisensory techniques, while 7 concentrate solely on the sense of smell. Additionally, one article examines the interaction between smell and taste. Four articles investigate how multisensory applications can enhance accessibility for visually impaired visitors, while 7 articles

discuss the use of relevant technologies, including augmented reality (AR) and virtual reality (VR).

A first group of studies used experimental or quasi-experimental designs to examine the effects of scent on visitors' perceptions, memory, evaluations, or interpretations. Aggleton and Waskett (1999) investigated whether certain scents in a museum enhance visitors' recall of exhibit information at the Jorvik Viking Centre. Participants completed memory tests under different scent conditions, allowing the authors to examine whether exposure to the same scents encountered during the original museum visit improved recall. Cirrincione (2014) studied the effects of ambient scents on how people perceive and remember art, emphasising factors such as perceived pleasantness, arousal, and recall of artwork. Participants were presented with talcum or citrus that varied in pleasantness while evaluating artworks created by two contrasting artists, Arcimboldo and Rothko, and the study examined perceived pleasantness, arousal, scent-artwork congruence, and memory. Vega-Gomez et al. (2020) extended this line of inquiry into a real museum setting by testing the influence of exhibition-congruent scents on visitors' perceptions and behaviours in González Santana Museum. Their study examined how olfactory marketing affected visitors' perceptions, evaluations, and behaviour. Zhang et al. (2023), on the other hand, focused on the role of olfactory stimuli within virtual museum environments. Their study used an olfactory display to investigate whether scent could help non-experts understand stylistic characteristics of Western landscape paintings, such as tone, mood, and genre.

A second group of empirical studies examined scent as part of broader multisensory museum experiences, often using mixed methods such as questionnaires, observations, interviews, and video analysis. Huang et al. (2018) designed and evaluated the effectiveness of mixed reality technologies in enhancing the visitor experience within museums and cultural heritage settings, focusing on engagement, discussion, and reflection. One of their exhibits, "Batu Boh," used sensor-based interaction to simulate food preparation and released fragrance as part of the experience. Wang (2020) explored the use of multisensory elements in historical exhibitions at the Taizhou Museum, including an odour generator that produced a fishy smell in the "People at the Seashore" section to evoke the atmosphere of a fishing village. Vaz et al. (2017) presented the "Mysteries of the Art of Healing" exhibition, designed to be accessible to blind and partially sighted visitors. They

included an olfactory experience in which visitors could engage with eight original pharmacy bottles from the collection, each containing pharmacological substances with distinctive odours. Verbeek et al. (2022) examined historically informed scented tours at the Rijksmuseum in Amsterdam, documenting different scent-delivery methods and the evaluation methodology for these initiatives. Wilson et al. (2020) focused on the needs of blind and partially sighted visitors in interpreting museum objects, with attention to how sensory properties, including scent, contribute to understanding museum objects.

A third group of studies consisted of case studies and design-oriented contributions that documented the development, implementation, and practical challenges of olfactory or multisensory museum applications. Chu et al. (2016) introduced sensory prototypes designed to evoke the historical and experiential elements of 16th-century prayer nuts through narrative design and sensory interactions. Their “Scents of Power” prototype used conceptual scents to convey historical meanings that could not be easily conveyed through text alone. Miotto (2016) introduced an olfactory delivery device designed for exhibitions related to Singapore’s culinary heritage. The device was designed to address challenges in odour diffusion, containment, ergonomic design, and maintenance, and was applied in several exhibition contexts. Carulli and Bordegoni (2019) discussed AR applications that integrated olfactory experiences into cultural heritage applications. In their examples, scents were released in response to visitors’ interactions with religious symbols, enriching the cultural and emotional impact of the experience. Blundell (2023) analysed three exhibitions that used smell and taste to enhance the museum experience, resulting in visitors who were more engaged and present. The main difference in this study was that it included cases in which scent served as a supporting sensory layer and those in which smell was the central focus of the exhibition.

The fourth group consisted of review articles that positioned olfactory and multisensory museum experiences within broader theoretical, technological, and accessibility-related discussions. Spence (2020) reviewed the use of ambient scent in art galleries and museums, with particular attention to how scents affect the visual perception of artwork. Cho’s (2021) review examined multisensory approaches to presenting visual art to individuals with visual impairments, including patterns, temperature, scent, music, and vibrations. Marto et al. (2022) conducted a systematic

review of multisensory virtual and AR applications in cultural heritage to explore how different stimuli can enrich multisensory experiences (immersion, realism, and engagement). Luo et al. (2024) provided an integrative review of multisensory museum experiences, focusing on the theoretical basis of multisensory experiences in museums, their features, and the impact of technology on sensory practices within museum contexts.

Across the analysed studies, several patterns emerge. First, olfactory stimuli were rarely used in isolation. In most studies, scent was combined with visual, tactile, auditory, gustatory, spatial, digital, or narrative elements. Second, the purpose of scent varied across contexts. In some studies, scent was used to improve memory or recognition; in others, to support emotional engagement, historical imagination, accessibility, immersion, or interpretation. Third, scent delivery methods differed substantially, ranging from bowls containing spices and incense, scented disks, pumps, blotters, and diffusers to odour generators, motion-activated devices, AR-supported olfactory displays, and controlled olfactory systems in virtual environments. Fourth, the visitor groups and evaluation methods also varied, with some studies focusing on general museum visitors, others on children, non-experts, visually impaired visitors, or participants in experimental settings. This diversity makes direct comparison difficult, but it also illustrates the scope of possible olfactory applications in a museum context.

3.2. Key Findings of Analysed Studies

The sense of smell is becoming increasingly important in museums and art galleries, which can adopt various approaches to incorporate scent. In museums, scents typically align with the exhibits' themes and meaning. In contrast, art galleries may use scents related to the artwork being viewed but not necessarily directly connected to it (Spence, 2020). Table 4 summarises the key findings discussed below.

Table 4: Key findings

Theme	Main findings	Research gap
Engagement and immersion	Scent can deepen engagement, memory, emotional responses, and interpretation, but effects are not uniformly positive.	More real-museum experiments needed.

Theme	Main findings	Research gap
Congruence and meaning	Scent works best when aligned with the exhibit narrative and supported by interpretation.	Test semantic congruence systematically.
Accessibility	Scent can support inclusive interpretation, especially for visually impaired visitors.	More studies with diverse visitor groups.
Technical implementation	Diffusion, fatigue, overlap, contamination, maintenance, and device noise are recurring problems.	Need for implementation standards.
Perceived value and satisfaction	Consumer-centred outcomes such as perceived value, perceived quality, and satisfaction are underdeveloped in the literature.	Future quantitative model testing.

The role of Scents in Creating More Personal and Engaged Visits

Several studies have shown that incorporating scents and other sensory elements, such as sound, touch, and taste, can enhance the visitor's experiences in museum exhibitions. For example, a case study from the USA explored prototypes featuring tactile elements and scents to increase interaction with the exhibit and enhance the experience. Participants reported that the sensory features led to a more personal and authentic experience (Chu et al., 2016). Similarly, Wang (2020) found that the multisensory exhibits effectively engage visitors. Increased visitors' engagement in the scented tour group was also observed in Verbeek et al.'s (2022) study. An interactive multi-sensory application focused on olfactory stimuli was also developed in Italy to enhance visitor experience and interaction (Carulli & Bordegoni, 2019). Blundell (2023) discussed how the sense of smell makes museum experiences more engaging, helping visitors interact with art, especially abstract pieces, in new ways. The results confirmed the effectiveness of this approach in encouraging diverse perspectives on and understanding of art. Vaz et al.'s (2017) study also confirmed that multisensory experiences are perceived as entertaining, pleasant, and satisfying. Verbeek et al. (2022) concluded that the sense of smell can enhance cultural heritage experience. It helps create a direct connection to the past, stimulates imagination, improves understanding of artworks' specific qualities, and enhances emotional responses to heritage.

A systematic review by Marto et al. (2022) examined technological multisensory applications in cultural heritage, focusing on how different stimuli impact multisensory experiences. They found that visitors exposed to experiences with and without scent reported that adding scent positively influenced their sense of spatial

presence and perceived realism compared with visual-only experiences. Additionally, Vega-Gomez et al. (2020) found that scent in a museum led to higher evaluations and more positive ratings than visits without scent. Verbeek et al. (2022) reached a similar conclusion, noting that the average rating for the scented tour was slightly higher than that for the non-scented tour. The visitors also found the experience highly immersive and received greater context. Marto et al. (2022) analysed various studies and found that multisensory experiences positively impacted users in 78,6% of cases, while only 21,4% were inconclusive, with no studies indicating a negative impact. They suggested numerous positive effects of multisensory experiences, including greater user involvement, stronger emotional responses, improved information interpretation, enhanced learning and communication, new ways of thinking, and greater immersion. Wang (2020) highlighted additional benefits of sensory experiences: increased satisfaction, enhanced overall museum experiences, the acquisition of cognitive knowledge, emotional connections, greater exhibition attractiveness, and longer visit durations. Verbeek et al. (2022) observed that smell influences visitors' talkativeness, as they shared scent-related observations and memories. This made them engaged with artworks for longer periods and with greater attentiveness.

However, Cho (2021) noted that adding scents to art does not always enhance the experience as expected. Spence (2020) noted that ambient scents could hinder art evaluation and lead to negative visitor ratings, regardless of whether the scents are perceived as pleasant or unpleasant. A study by Vega-Gomez et al. (2020) evaluated how scent impacts behaviour and assessment of museum visits, finding that scent does not directly influence spending behaviour or the perceived quality of the museum. Additionally, it does not affect the visitors' choices between museums with the same theme and category. The findings also confirm that the scent does not change the perceived space or the number of people present. However, further analysis is needed to determine whether the scent's effect is direct or indirect through improvements in other variables, and whether the lack of influence on museum selection is due to the specific nature of the examined scent or to other overriding factors. Finally, Zhang et al. (2023) confirmed that olfactory experiences in virtual museums can enhance understanding of stylistic elements in Western landscape paintings; however, olfactory interventions improved only the accuracy of genre recognition and perception of style information, but not the recognition of the artist's mood. Furthermore, the olfactory aids specifically increased the capture of

style information for Romantic and Impressionist painting but negatively impacted the perception of realism.

The importance of Alignment and Meaningful Use of Scents

A case study from the USA suggests that providing clear guidance on sensory interactions can enhance participation, rather than confusing visitors or causing disengagement (Chu et al., 2016). Wang (2020) also found that the best results are achieved by combining multisensory elements with other presentation methods. Additionally, Zhang et al. (2023) noted that only two participants accurately identified all the scents used, underscoring the need for textual or other aids to help visitors recognise the smells. Verbeek et al. (2022) highlighted that the combination of the tour guide's input and the smell enhances the overall experience.

Blundell (2023) warned that overwhelming visitors with excessive sensory input could divert their attention from the art and its message. Spence (2020) further noted that a mismatch between scent and visual displays could distract visitors. One visitor of the scented tour commented that the fragrance distracted them from the artwork. Therefore, scents must be semantically aligned with the artworks to evoke positive responses from visitors. This alignment has been shown to increase visitors' willingness to return to a museum, as confirmed by Cho (2021) and Vega-Gomez et al. (2020). Zhang et al. (2023) also observed that mismatched scents, overly strong odours, and personal associations with certain smells could lead visitors to feel disconnected from the artwork, potentially diminishing their immersion in the museum experience. They also confirmed that matching odours to participants' expectations led to a more immersive experience. However, Cirrincione et al. (2014) found that participants rated paintings more arousing when paired with incongruent scents. This phenomenon can be understood as the additional effort required to comprehend the incongruence. This extra effort heightens attention and increases the level of perceived arousal of the specific painting.

The impact of Scents on Diverse Audiences

In studies exploring multisensory approaches, researchers have found that visitors perceive and respond to scents differently. While multisensory stimuli can effectively engage visitors, their impact varies across individuals due to differences in sensory

perception and personal experiences (Wang, 2020). Zhang et al. (2023) highlighted the importance of tailoring flavour choices to the preferences of different audiences, indicating the need to adapt sensory experiences according to the target audience's sensory preferences. According to a study by Spence (2020), ambient scent might affect women more than men. Vega-Gomez et al. (2020) also concluded that the effects of scent can vary based on the visitor's gender. Luo et al. (2024) emphasise that sensory possibilities play a crucial role in exhibition design, especially for children, as they offer new ways to experience artworks, access information, and perceive various phenomena. Blundell (2023) suggests involving potential visitors in the planning of multisensory experiences, as this is crucial for ensuring their success. Additionally, Wilson et al. (2020) highlighted the importance of olfactory properties in how blind and partially sighted visitors perceive and understand objects. Visually impaired participants in the study by Verbeek et al. (2022) emphasised that smell stirred their imagination, helped them feel more connected to artworks, highlighted the function of objects, and enhanced their memories, as they could describe smells in detail.

These approaches allow individuals with different sensory abilities to understand better exhibited items and artworks. In her review, Cho (2021) discussed methods for transforming visual art elements through sensory experiences, including scent. This approach aims to provide a fresh perspective on art appreciation while enhancing cultural enjoyment and accessibility for the visually impaired, as confirmed by Verbeek et al. (2022).

Different Scents and Their Impact on Visual Art Perception

Researchers have examined various pleasant and unpleasant ambient smells and concluded that while pleasant scents may improve mood and encourage engagement with exhibits, unpleasant scents can significantly enhance immersion in an experience (Spence, 2020). Similarly, participants in the study by Zhang et al. (2023) preferred more objective odours that reflected artists' biographies, including unpleasant ones. Spence (2020) also discusses the concept of sensation transference, which suggests that people's feelings toward a scent can affect their evaluation of visual art. Interestingly, negatively valenced smells seem to have a greater impact on people's ratings than positive ones.

The Relationship Between Scents, Colours, and Other Sensory Elements

Research indicates that scents are most effective when combined with other sensory elements such as colours, sounds, and temperature. For instance, a Korean study found that linking scents to shapes, colours, temperatures, or sounds can create a richer, more engaging experience for users (Cho, 2021). Cho (2021) concludes that scents should complement, rather than replace, other modalities to enhance meaning and improve the overall visitor experience. Participants in a study by Zhang et al. (2023) also suggested incorporating additional sensory elements to enrich the olfactory experience. Researchers underscore the influence of scents associated with specific colours in attracting attention to areas of a scene that feature similar colours (Spence, 2020). Verbeek et al. (2022) observed that smell can direct visitors' eyes to previously overlooked details and shift their attention to the overall atmosphere of the depicted scene. They recommend using eye-tracking devices to measure time spent on each artwork, both with and without scent, to confirm this observation. However, Cho (2021) acknowledges that the sense of smell has limitations when expressing colours. Cirrincione et al. (2014) provide recommendations for future research to explore interactions among senses and their combined effects on the perception of art. In Portugal, research has shown that combining scents with other senses, such as touch and sound, creates more holistic and inclusive experiences. This approach benefits not only visually impaired visitors but also the broader public (Cho, 2021; Vaz et al., 2017).

Challenges and Limitations in the Use of Scents

Although scents can enhance experiences, research indicates that improper use can lead to olfactory fatigue, in which the olfactory system becomes overwhelmed and temporarily unresponsive (Miotto, 2016; Verbeek et al., 2022; Wang, 2020). However, if the odour concentration is too low, the scent may fail to produce the desired impact (Miotto, 2016). Verbeek et al. (2022) therefore suggest different strategies for neutralising the nose and organising scents, from least intensive to most intensive at the end of the tour. Since the sense of smell is highly subjective, different individuals often have diverse opinions and reactions to specific scents, which can complicate a shared olfactory experience among museum visitors (Wang, 2020). Wang (2020) also highlights the challenge of accurately evaluating the impacts of multisensory exhibits on individuals with varying sensory abilities.

Moreover, several studies highlighted the technical difficulties, particularly the challenge of evenly distributing scents without them overlapping (Cho, 2021). Combining various scents within the same museum area can lead to the “garbage effect”, resulting in an unpleasant odour (Miotto, 2016). Wang (2020) discusses the challenges of controlling the amount of scent released and achieving completely odourless museum spaces, as factors such as temperature, air circulation, and humidity influence the existing scents.

Zhang et al. (2023) highlight another challenge related to the odour release mechanism's noise, which distracted visitors from fully immersing in the experience. A case study from the USA emphasised the importance of ensuring that scents can be easily housed and replaced without direct contact with visitors' skin (Chu et al., 2016). This indicates a need for improved technology that enables precise, sustainable scent delivery, as well as effective methods for maintaining scent freshness over time. Since odorants are inherently consumable and often degradable, the odour diffusion method must also account for the need to replenish and maintain these scents, especially in the context of permanent exhibitions intended to last several years (Miotto, 2016). Marto et al. (2022) emphasised the uncertainty regarding the most effective methods for incorporating smell into cultural heritage experiences, noting that some studies utilised perfumes or oils, while others employed olfactory displays or a basic version of Computational Fluid Dynamics (CFD).

Wilson et al. (2020) discuss the challenges of replicating olfactory characteristics without additional processing or scent additives, as some materials have inherent smells that may interfere with how objects are perceived. Furthermore, it was observed that people tend to prefer synthetic smells over authentic ones, since historical scents may not resonate with modern visitors in the same way they did for those who encountered them regularly in the past (Spence, 2020). In contrast, Verbeek et al. (2022) found that historically informed scents are more appreciated than more synesthetic creations. Blundell (2023) also emphasises the tendency to favour synthetic scents instead of using natural scents, as they could potentially affect the artworks' materials. It is important to control odours to prevent artefacts from unwanted contaminations (Miotto, 2016; Verbeek et al., 2022).

Several studies have indicated that visitors often do not actively engage with olfactory experiences or struggle to recognise them. While an olfactory delivery device featured in Singapore's culinary heritage exhibit was well received by visitors, who expressed enthusiasm for experiencing different scents (Miotto, 2016), which was also observed among participants in Verbeek et al. (2022) study, a case study from the USA points out that visitors' engagement with the scents tends to be brief (Chu et al., 2016). For example, research conducted in Malaysia revealed that while children noticed and commented on scents, they did not connect them to the exhibition content. This indicates a need for better guidance in using scents to enhance engagement and reflection (Huang et al., 2018). Verbeek et al. (2022) emphasise the need for staff to learn to work with smells. For this purpose, they created a smell manual that includes essential guidelines for working with scents. These guidelines recommend practices such as smelling in silence first, avoiding requests for participants to label a scent, and encouraging discussions about connections to the artwork. Evaluating, differentiating and reflecting on the scents would probably also require repeated or more profound inhalations (Chu et al., 2016). Additionally, a study from the United Kingdom concluded that the sense of smell was the least utilised, even among blind and partially sighted individuals (Wilson et al., 2020). Marto et al. (2022) also reported that scent is often regarded as less significant compared to taste, visual, and auditory stimuli. Cho (2021) found that blind and visually impaired visitors tend to use scents more as a complement to their other senses, while scent plays a lesser role for those who primarily rely on sight and hearing.

The Impact of Scents on Memory and Learning

Aggleton and Waskett (1999) found that exposure to the same scents experienced during a previous museum visit significantly enhances visitors' ability to remember the exhibits, supporting the principle of encoding specificity. This principle suggests that elements of the environment in which learning takes place, such as a museum, can enhance memory when those elements are present later. Their study is notable for being the only one to utilise a real-world setting to measure memory recall over an extended period, providing strong evidence for the effectiveness of scents in aiding memory. However, it did not formally test whether scents evoke emotional reactions that could enhance memory retention. Cirrincione et al. (2014) later observed that the effect of scent on memory was direct rather than mediated by its

emotional valence. Miotto's (2016) case study on an olfactory delivery device emphasises the importance of smell in evoking personal memories and shaping visitors' emotional experiences. Carulli and Bordegoni (2019) also discuss the potential of interactive multisensory applications to improve long-term memory retention of exhibition information. Verbeek et al. (2022) also recognise the role of smell in increasing the memorability of a museum visit. Marto et al. (2022) and Cho (2021) recognise the role of smell in recalling personal memories and eliciting emotions. Vaz et al. (2017) study participants also mentioned that the sense of smell contributed to their learning about the pharmacological substances available at the portable pharmacy. Conversely, Spence (2020) highlights how ambient scents can hinder memory retention. Cirrincione et al. (2014) also suggest that the pleasant ambient scent can decrease evaluations and hinder memory of art in a virtual exhibition. Verbeek et al. (2022) highlight the need for more detailed background information about the scents to enhance visitors' knowledge.

Innovative Ways of Using Scents and Technology

Some studies have investigated the use of advanced technologies, such as scent delivery devices and virtual reality (VR), to create more immersive experiences. For instance, an Italian study employed interactive AR applications that incorporated scents, creating deeper emotional connections and more lasting memories of exhibitions (Carulli & Bordegoni, 2019). This innovative approach demonstrates promising potential for enhancing cultural experiences through technology. Marto et al. (2022) examined various multisensory technological applications in cultural heritage, while Luo et al. (2024) highlighted the crucial roles of sensory cues and technology in exhibition design. Additionally, Huang et al. (2018) focused on creating and evaluating the effectiveness of mixed-reality technologies in enhancing the visitor experience in museums. Blundell (2023) also focuses on the creative use of technology, such as the AirParfum machine, which allows smelling multiple fragrances without saturating the senses while also communicating with external devices.

Research Approaches, Methods, and Limitations of Analysed Studies

Carulli and Bordegoni (2019) discuss the relatively uncommon use of olfactory stimuli and multisensory approaches in cultural heritage exhibitions. Similarly, Marto et al. (2022) note that scent, compared to other senses, has been under-researched and underused in museums. They also highlight that most studies analysing scent experiences involve at least one other stimulus. As outcomes vary with the specific stimuli used, further research is needed to understand better how sensory stimuli affect visitors' experiences. In Portugal, a systematic review has highlighted the lack of standardisation in the implementation of multisensory experiences. This inconsistency makes it difficult to compare methods and establish common guidelines for effective sensory approaches (Marto et al., 2022).

Spence (2020) identifies a significant limitation in many of the reviewed studies: they lack validity because they were conducted in laboratory settings, where participants viewed art reproductions for only brief periods. This limits the general applicability of findings to real museum settings. Such artificial setups can lead to unnatural reactions; participants may not exhibit the same feelings and behaviours as they would in an actual museum environment. Cirrincione et al. (2014) suggest testing whether their findings apply to real art galleries and museums to ensure broader relevance. Blundell (2023) emphasises the importance of collecting visitor feedback, as it can yield more accurate and valuable information. Huang et al.'s (2018) study is further limited by the absence of a control group to compare learning outcomes with and without technology augmentation. The study by Verbeek et al. (2022) also lacks a control group. Many studies have focused on the short-term effects of scents on visitors, while few have examined their long-term effects. More research is needed to understand the sustainability of sensory interventions over time (Aggleton & Waskett, 1999).

Miotto (2016) highlights that there is no formal collection of feedback on these olfactory experiences. Marto et al. (2022) also noted the lack of unanimous data regarding visitors' opinions or feelings about scent experiences, as this was not the primary focus of the analysed studies. On the other hand, Spence (2020) highlights a significant limitation in the studies reviewed, which primarily focus on small, specific participant samples, such as students or visitors from certain demographic groups (e.g. WEIRD – Western, Educated, Industrialised, Rich, and Democratic).

These groups do not adequately represent the diverse museum visitor population. This is particularly crucial in studies examining how scents influence artistic evaluation, as the results may be biased and reflect only particular cultural or social norms. Additionally, most studies did not provide participants with a reason to associate the smell with the visual display, which may have affected their ratings, underscoring the importance of a guided sensory experience (Spence, 2020).

Cirrincone et al. (2014) tested only two scents and two artists, suggesting that further studies should expand on this. A study from China also recommended incorporating a wider variety of painting categories to strengthen the study's findings, as the limited types of painting used in their experiment can hinder generalisations about art appreciation (Zhang et al., 2023). Additionally, the research by Vega-Gomez et al. (2020) underscores the necessity for further research using larger sample sizes and multiple museums to validate their findings. Zhang et al. (2023) also emphasise the importance of broader participant recruitment in future studies.

Meanwhile, Cho (2021) developed a multisensory expression and delivery tool that acts as an educational tool, improving the accessibility and usability of products and artworks through multimodal interaction. Additionally, Luo et al. (2024) identified six key response qualities in visitor-exhibition interactions: experience dimensionality, duration, attention, sensory intensity, emotional valence, and engagement level. However, further exploration is needed to understand how these qualities influence interactions.

4 Discussion

This systematic review set out to synthesise published research on olfactory stimuli in museum and gallery contexts, identify what is currently known about their effects on visitors, and derive implications for museum practice and future research. Overall, the reviewed literature suggests that smell can enrich museum experiences, but not in a simple or universally positive manner. Rather than functioning as an inherently beneficial add-on, olfactory stimulation appears to operate as a context-dependent amplifier whose effects depend on how well it is integrated into the exhibition narrative, how it is technically delivered, and how it is interpreted by different visitor groups. This is an important conclusion because it moves the discussion from the question of whether olfactory stimuli “work” in this

environment, toward the deeper questions of when, how, and for whom they improve the museum experience.

4.1 The effects of olfactory stimuli are ambiguous

A first major insight from the review is that olfactory cues can deepen engagement, stimulate imagination, support memory, and make encounters with heritage and artworks feel more vivid and personal (Aggleton & Waskett, 1999; Blundell, 2023; Chu et al., 2016; Verbeek et al., 2022). Across the included studies, scent was associated with stronger immersion, richer interpretation, increased talkativeness and socialisation, stronger affective reactions, and, in some cases, improved recall and learning (Aggleton & Waskett, 1999; Marto et al., 2022; Vaz et al., 2017; Verbeek et al., 2022; Wang, 2020). At the same time, the evidence does not support a uniformly positive effect. Some studies reported null effects (e.g. Vega-Gómez et al., 2020), while others suggested that scent can hinder evaluation, distract from artworks, or impair certain aspects of memory or realism judgments (Blundell, 2023; Cirrincione et al., 2014; Spence, 2020; Zhang et al., 2023). Taken together, the literature suggests that scent should not be conceptualised as a universally positive atmospheric building piece, but as a stimulus that can intensify experience in both desirable and undesirable directions. In that sense, smell seems less like a direct driver of positive outcomes and more like a mechanism that heightens attention, affects, and interpretive processing.

4.2 Olfactory stimuli require congruence and interpretive support

A second major insight concerns congruence and meaningful use of olfactory stimuli. The review consistently indicates that olfactory stimuli are most effective when visitors can make sense of them in relation to the object, artwork, space, or the story being presented. Historically informed scents, semantically aligned odours, and combinations of smell with narrative guidance or interpretive framing appear especially promising (Chu et al., 2016; Spence, 2020; Verbeek et al., 2022; Zhang et al., 2023). By contrast, mismatched or insufficiently explained odours and scents can confuse visitors, break immersion, or shift attention away from the exhibition's intended meaning (Huang et al., 2018; Spence, 2020; Verbeek et al., 2022; Zhang et al., 2023). Importantly, congruence is not only a technical design issue but also a curatorial and communicative one (Chu et al., 2016; Huang et al., 2018; Spence, 2020;

Verbeek et al., 2022; Zhang et al., 2023). Visitors may fail to recognise the intended scent, may interpret it through personal memories, or may simply not understand why it is present. This means that scent should rarely be treated as a self-explanatory device. In many settings, its value seems to depend on accompanying cues such as verbal interpretation, textual explanation, guided tours, or integration with other sensory and visual elements.

4.3 Opportunities and constraints of olfactory stimuli implementation

Third, the review shows that smell is especially promising when understood as part of a multisensory system rather than as an isolated intervention. Several studies (e.g. Carulli & Bordegoni, 2019; Cho, 2021; Huang et al., 2018; Marto et al., 2022; Vaz et al., 2017; Zhang et al., 2023) propose that olfactory cues work best when combined with touch, sound, spatial design, or digital technologies such as AR and VR. This is particularly relevant in museum environments, where visitors do not experience exhibitions through a single sensory channel. The contribution of scent may therefore lie less in replacing visual interpretation and more in enriching it, redirecting attention, increasing realism, evoking associations, and supporting embodied meaning-making. This also helps explain why scent appears particularly valuable in accessibility-oriented settings. For visually impaired visitors, for instance, olfactory cues may strengthen imagination, object understanding, emotional connection, and memory (Cho, 2021; Vaz et al., 2017; Verbeek et al., 2022; Wilson et al., 2020); for other visitors, they can broaden the exhibition's experiential repertoire (Blundell, 2023; Marto et al., 2022). Thus, the review supports the view that olfactory design should be embedded within broader multisensory experience design and inclusive museum practice.

At the same time, the literature makes clear that implementation is far from straightforward. The reviewed studies repeatedly highlight problems such as olfactory fatigue, weak diffusion, excessive intensity, scent overlap, contamination risks, maintenance demands, device noise, and the difficulty of sustaining scent quality over time (Cho, 2021; Chu et al., 2016; Miotto, 2016; Verbeek et al., 2022; Wang, 2020; Zhang et al., 2023). In addition, the highly subjective nature of smell complicates standardisation: visitors differ in sensitivity, preferences, memories, expectations, and even willingness to engage actively with olfactory cues (Miotto, 2016; Wang, 2020; Zhang et al., 2023). These findings are important because they

show that the success of scented exhibitions or exhibits cannot be reduced to curatorial creativity alone. It also depends on operational capabilities, staff training, environmental control, and clear protocols for scent delivery (Marto et al., 2022; Miotto, 2016; Verbeek et al., 2022; Wang, 2020). This review highlights several practical principles for using scents in exhibitions. It suggests that scents should be used selectively rather than decoratively and should be closely aligned with the exhibition's theme and narrative. Additionally, it's important to help visitors interpret these scents while carefully managing their intensity and sequencing. Considerations for accessibility, maintenance, and preventing sensory overload are also crucial. These rather broad guidelines further emphasise the fact that the field still lacks comprehensive, practical standards for designing, sequencing, explaining, and evaluating olfactory experiences in museums.

4.4 Apparent need for more rigorous and visitor-centred research

A fourth key conclusion concerns the state of the evidence base itself. The reviewed literature is still fragmented. The body of work includes case studies, reviews, and a limited number of empirical studies, often with small samples, narrow visitor groups, artificial settings, insufficient control conditions, and inconsistent outcome measures. Many studies focus on short-term reactions rather than lasting learning, memory, satisfaction, or revisit behaviour. Smell is also often embedded in broader multisensory interventions, making it difficult to isolate its specific contribution. As a result, the field currently provides suggestive rather than cumulative evidence. The strongest overall conclusion is therefore not that museums should simply diffuse more scents, but that olfactory design deserves more rigorous and visitor-centred investigation.

There is one additional implication of this review: the need for a more explicit service and marketing perspective in future research on olfactory museum experiences. While the reviewed studies provide valuable evidence on engagement, immersion, memory, interpretation, accessibility, and implementation challenges, they pay far less systematic attention to how olfactory stimuli affect broader evaluative dimensions of the museum service encounter. In particular, the literature remains fragmented regarding perceived quality, perceived value, and overall visitor satisfaction, even though these constructs are central to understanding museum

experiences from a customer-centric perspective introduced at the beginning of this study.

This gap is particularly relevant given the patterns identified in the reviewed studies. If scent can increase immersion, enrich emotional and cognitive responses, stimulate personal memories, guide attention, and shape the meaningfulness of the visit, then it is reasonable to ask whether these effects also translate into higher perceived service quality, greater perceived value, and stronger overall satisfaction – also under different moderating conditions. From this perspective, the perceived value framework outlined below can be understood not as a direct conclusion of the existing evidence, but as a structured response to the gap revealed in this review.

4.5 Future research framework: olfactory stimuli, perceived value, and satisfaction

Perceived quality, perceived value, and customer satisfaction play a central role in evaluating marketing activities from the customer perspective and significantly impact museum performance. Therefore, further in-depth study of these aspects in relation to smell is needed to understand their overall impact on the customer experience in the museum environment.

Perceived value is a fundamental construct in consumer behaviour, influencing decision-making and satisfaction with products and services. It refers to the balance between the benefits consumers receive and the costs they incur (Zeithaml, 1988). It is essential to recognise that both benefits and costs can take various forms. For instance, Sheth et al. (1991) highlighted five benefits: functional, social, emotional, epistemic, and conditional. Conversely, costs can be categorised into monetary and non-monetary, including time and effort, as well as perceived risks associated with the purchase and/or use of a product or service.

Perceived value is thus treated as a multidimensional construct, applied across various domains, including cultural institutions, where both tangible and intangible aspects of value are pivotal for the customer experience (Armbrecht, 2014). Understanding perceived value is also significant for museums. The concept transcends immediate benefits, encompassing emotional, social, and cultural dimensions essential for engaging visitor experiences.

A review of museum management literature also reveals a lack of attention to the perceived value of museum services and their measurement, except for a few academic contributions. Hume (2011) emphasised that museum strategy should focus on the holistic visitor experience. Museums should consider the heterogeneity of visitor expectations and design strategies tailored to customers' needs and desires. Accounting for all service quality dimensions is crucial for enhancing perceived value and long-term museum success. The author also notes that perceived value in the museum context is often multifaceted, as museums combine educational, cultural, and pragmatic aspects. Therefore, museums aiming to attract and retain visitors must consider these dimensions in creating a comprehensive experience, as the decision to revisit is influenced by the value delivered to individual visitors.

In the service sector, a widely accepted conceptualisation of perceived value was developed by Petrick (2002) with the SERV-PERVAL model, defining five dimensions: (1) Quality, (2) Emotional response, (3) Monetary price, (4) Behavioural price, and (5) Reputation. These components are critical in-service environments, including museums, where non-monetary sacrifices significantly influence the perceived value of the service. Non-monetary costs may include time spent visiting the museum, effort required to explore exhibits, or cognitive load needed to process extensive information. While service quality is paramount in this context, emotional responses also profoundly impact the customer experience. This model was previously adapted to measure perceived value in organisations representing various fields, from hospitality to insurance and banking. The available literature and collaboration with museum professionals could be used to evaluate the role of scent in relation to museums' perceived service value.

Further studies should therefore investigate how scent contributes to the complex perception of value in museum settings. Additionally, research should explore how scent enhances the visitor experience and overall satisfaction, and how these factors interact. According to this literature review, illustrated in Figure 2, the effects of perceived quality, emotional responses, perceived monetary and non-monetary value, and social value on overall satisfaction should be further examined when scent is integrated into museum services. Based on what has been elaborated, the following propositions can be applied:

P1: Including scent in a museum exhibition increases visitors' perceived quality compared to exhibitions that do not incorporate scent.

P2: Including scent in a museum exhibition increases visitors' emotional response compared to exhibitions that do not incorporate scent.

P3: Including scent in a museum exhibition decreases visitors' perceived monetary and non-monetary costs compared to exhibitions that do not incorporate scent.

P4: Including scent in a museum exhibition increases visitors' social value compared to exhibitions that do not incorporate scent.

P5: Including scent in a museum exhibition increases visitors' overall perceived value compared to exhibitions that do not incorporate scent.

P6: Including scent in a museum exhibition increases visitors' overall satisfaction compared to exhibitions that do not incorporate scent.

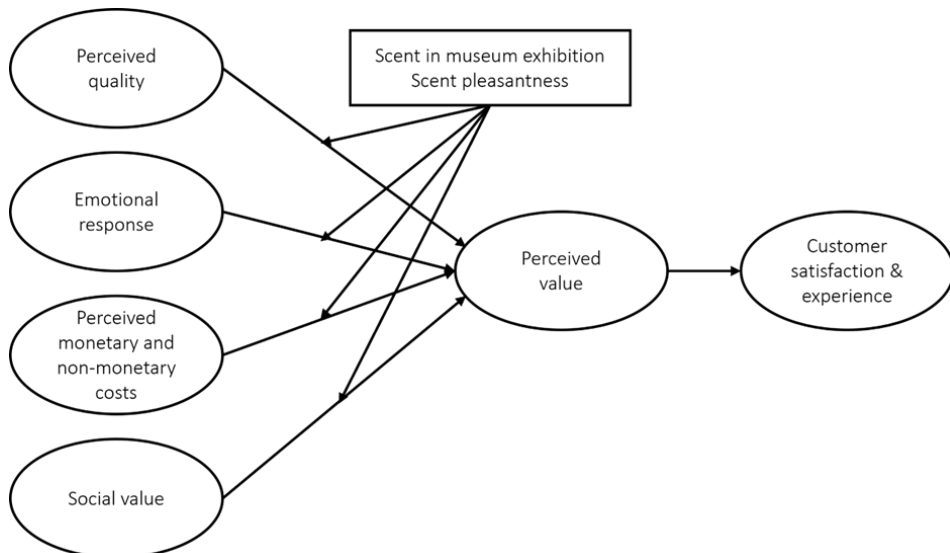


Figure 2: Proposed conceptual model of perceived service value for museums

Source: own

These propositions are not presented as empirically confirmed conclusions of the present review. Rather, they are offered as a future research framework derived from the identified gap in the literature, namely the limited integration of olfactory museum research with service quality, perceived value, and satisfaction constructs.

This review further shows a lack of research studies with an experimental design that includes a control group not exposed to scent alongside the experimental group. Such studies are crucial for understanding the moderating impact of scent on cause-and-effect relationships and for reducing bias in interpreting results. The subjective nature of scent perception also poses an important challenge. The pleasantness or unpleasantness of smell, which emerges as a central theme in the literature, remains under-researched in its role in improving or degrading museum service quality, perceived value, and visitor satisfaction. In the future, special attention will be needed to develop models of the perceived value of museum services that capture users' cognitive, emotional, and behavioural responses to olfactory stimuli. Based on the above, we propose further studies to test the basic concepts of the perceived value of museum services in two groups of visitors: those exposed to olfactory stimuli and those not.

According to that, we propose:

P7: Including scent in a museum exhibition moderates the relationships between visitors' perceived quality, emotional response, perceived monetary and non-monetary costs, social value, and visitors' overall perceived value.

Such a conceptual framework could be applied in measuring the contribution of sensory elements in museum exhibits. The introduction of sensory elements, such as scent, can enhance emotional and social engagement among visitors. Scents can evoke historical connections and nostalgic feelings, enriching the emotional experience and potentially increasing the authenticity of exhibits and displays. Measuring emotional responses (e.g., using the PAD model – pleasure, arousal, dominance) would also be appropriate in this context, as scents are closely linked to emotional experiences (Russel & Mehrabian, 1974).

4.6 Managerial implications

The findings of this review have important implications for museum management and exhibition design. Most importantly, olfactory stimuli should not be treated as merely decorative atmospheric elements, but as intentional part of the visitor experience. The reviewed studies suggest scents can boost engagement, immersion, emotions, memory, interpretation, and accessibility, but effects are not automatic or always positive. Museums must approach scent design purposefully and systematically, guided by the exhibition's interpretive goals. Scents are most effective when connected to displayed objects or themes, with contextual cues helping visitors understand their relevance. Olfactory stimuli should be integrated with other senses to enhance immersion, historical imagination, embodied learning, or accessibility, avoiding excessive stimulation that distracts visitors. Implementation requires careful planning of scent intensity, duration, diffusion, ventilation, and maintenance, with pilot testing recommended. Evaluation should go beyond noticing or liking scent, assessing its impact on understanding, engagement, perceived quality, satisfaction, accessibility, and revisit willingness. The key challenge is designing meaningful, inclusive olfactory experiences aligned with museum goals.

5 Conclusion

This review shows that olfactory stimuli can enrich museum experiences by deepening engagement, supporting memory, stimulating imagination, and enhancing interpretation, but their effects are neither simple nor uniformly positive. Their success depends on congruence, interpretive support, multisensory integration, and careful implementation. At the same time, the evidence base remains methodologically fragmented, limiting the ability to draw strong cumulative conclusions. Overall, the review suggests that scents and odours should be treated not as a decorative addition, but as a potentially powerful yet demanding component of museum experience design. For museum practice, this implies selective, meaningful, and well-supported implementation. For future research, it implies the need for more rigorous and visitor-centred studies, including work that examines how olfactory stimuli may shape broader evaluative outcomes such as perceived quality, perceived value, and satisfaction.

Endnotes

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CORPORATE SUSTAINABILITY DUE DILIGENCE AS A TRANSFORMATIVE ELEMENT OF EU CORPORATE LAW

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The regulation of corporate conduct with respect to environmental and human rights impacts has assumed increasing prominence in EU company law, reflecting developments in corporate sustainability law. This article examines the development of corporate sustainability law in the EU, focusing on corporate sustainability due diligence as a component of EU corporate law and an emerging framework shaping corporate responsibilities. It analyses the Omnibus I reform of the Corporate Sustainability Due Diligence Directive (CSDDD) and evaluates its implications for company law and corporate governance. The article explores the simplifications introduced by the reform, particularly regarding the scope and structure of due diligence as a risk-based, continuous system for identifying, preventing, mitigating and accounting for adverse impacts. It argues that, notwithstanding these adjustments, due diligence remains a legal standard of corporate governance. At the same time, the reform narrows the circle of obligated companies and underscores the need for coherent implementation.

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1 Introduction

The development of EU corporate law increasingly reveals a fundamental shift in the understanding of companies' roles and responsibilities in the modern economy. Alongside traditional objectives, such as the efficiency of the internal market, the protection of shareholders and the freedom of economic initiative, growing emphasis is being placed on the requirement of corporate sustainability responsibility. This encompasses the obligation of companies to systematically consider environmental impacts and respect for human rights in the course of their operations, not only within the framework of their own activities, but also in the broader context of their business relationships and value chains. Such a normative expansion of corporate responsibility represents a qualitative transformation at the core of EU corporate law.

The concept of due diligence in corporate sustainability is a central legal mechanism in this development. In its evolution, due diligence has gradually moved away from soft-law foundations, characterised by recommendations and international standards. It has increasingly emerged as a legally binding standard that substantively guides the conduct of companies and their corporate bodies. The Corporate Sustainability Due Diligence Directive (CSDDD) consolidates this normative shift by embedding sustainability responsibility within the very structure of EU corporate law. It requires companies to establish a comprehensive, continuous and risk-based system aimed at identifying, preventing, mitigating and bringing to an end actual and potential adverse environmental and human rights impacts. In this way, the framework of legally relevant corporate conduct is significantly broadened, extending beyond the traditional understanding of the duty of diligent business management.

The amendments introduced through the so-called Omnibus I Directive, which intervene in the original structure of the CSDDD, further raise questions regarding the scope and intensity of corporate sustainability responsibility. Although these legislative adjustments introduce certain simplifications while simultaneously narrowing the circle of obligated entities, they do not abandon the fundamental normative premise that due diligence constitutes an integral element of responsible corporate governance. On the contrary, the amendments reaffirm due diligence as a general legal standard whose content adapts to evolving regulatory and economic

circumstances, while preserving its legally binding and systemically relevant role. In such circumstances, the question arises whether the amendments under consideration constitute a genuine normative retreat or primarily an adjustment of the modalities for pursuing sustainability objectives within EU corporate law.

Against this regulatory and doctrinal background, the central research question of this chapter emerges, namely: to what extent due diligence in the field of corporate sustainability, as regulated under the reformed Corporate Sustainability Due Diligence Directive, constitutes a transformative legal standard in EU corporate law, and how this standard reshapes the understanding of corporate sustainability responsibility and corporate governance. To answer this question, a legal-analytical examination was undertaken of the EU normative framework, its position within the broader system of corporate and commercial law, and the implications of the reform for the implementation and effectiveness of corporate sustainability responsibility within the national legal orders of the Member States.

2 Methodology

This chapter is based on qualitative legal research that combines both classical and contemporary methodological approaches in legal scholarship. The central research method consists of a doctrinal analysis of EU law, directed towards the interpretation, systematisation and normative positioning of CSDDD, the amendments introduced through the Omnibus I package, and the related institutes of corporate and commercial law. The analysis does not remain confined to a descriptive presentation of legal norms but also includes their critical assessment from the perspective of coherence, legal certainty and functional effectiveness. Substantively, the analysis focuses on the legal nature of due diligence obligations, whether they constitute obligations of conduct or obligations of result, and on their position within the existing framework of the duties of administrative, management, and supervisory bodies. Particular attention is also devoted to the relationship between the new due diligence obligations and the traditional fiduciary duties of directors, as well as to the legal consequences of non-compliance, particularly from the perspectives of civil and administrative liability, and the potential misdemeanour liability of companies. The analysis, therefore, extends beyond the purely normative level to encompass questions of practical implementation and enforcement.

Using systematic and teleological methods of interpretation, the rules on due diligence are examined in the broader context of the development of sustainability law in the EU. In this regard, particular consideration is given to the interconnections with other relevant legislative instruments, such as the Corporate Sustainability Reporting Directive (CSRD), the Taxonomy Regulation and the Action Plan on Financing Sustainable Growth, as well as to the fundamental objectives of the Union in the fields of sustainable development, the protection of human rights and the functioning of the internal market. Such an approach enables a more in-depth assessment of whether the amendments introduced through the Omnibus I package constitute a genuine normative departure from the originally conceived framework or merely its adaptation to changing economic and political circumstances, and to what extent those amendments affect the effectiveness of achieving sustainability objectives.

In order to understand the development of due diligence as a legal standard, a historical-developmental method is also employed, analysing the transition from international soft-law standards, such as the UN Guiding Principles (UNGPs) and the OECD Guidelines, towards their gradual internalisation into binding EU law and their subsequent normative evolution through legislative reforms. This method enables a more comprehensive understanding of the genesis of the due diligence concept. It reveals the dynamics of its transformation from non-binding guidance into a legally binding framework. At the same time, it sheds light on both continuity and discontinuity in the development of the concept of corporate sustainability responsibility. It enables a more profound assessment of its current significance and future development within the EU legal order.

3 **Analysis**

3.1 The Development of Sustainable Corporate Governance in the European Union

Over the past decade, the EU has systematically developed a legal framework in the fields of sustainable corporate governance and sustainable finance. In academic literature, the term sustainable corporate governance is used as a research and conceptual framework linking corporate governance, particularly the relationships between management, shareholders and stakeholders, with sustainability objectives,

including environmental protection, human rights and the creation of long-term value. Sustainable corporate governance is understood as an expanded fiduciary duty of directors, according to which directors should not be confined solely to the pursuit of short-term shareholder interests, but should also take into consideration the long-term interests of the company and its broader stakeholders (Bohinc, 2024, 2023; Sjøfjell, 2022; Primec, 2024b; Lidman, 2022).

Following the adoption of the UN 2030 Agenda for Sustainable Development (United Nations, 2015a) and the signing of the Paris Climate Agreement in 2015 (United Nations, 2015b), the EU focused on activities to achieve the Sustainable Development Goals and transition to a carbon-neutral society by 2050. In 2019, these efforts were further strengthened by the adoption of the European Green Deal, the principal strategy for developing a green and digital Europe over the subsequent five-year period. This political strategy was followed by legislative measures aimed at a sustainable future. Alongside legislation on sustainable corporate governance, legislation on sustainable finance also plays a significant role, particularly as it is founded upon the Commission's 2018 Action Plan on Financing Sustainable Growth (European Commission, 2018). Effective sustainable finance requires redirecting capital flows towards investments supporting sustainable growth, including the management of financial risks arising from climate change, resource depletion, environmental degradation, and social issues, as well as the promotion of transparency and the long-term orientation of financial and economic activities. A prerequisite for achieving these objectives is the availability of adequate, comparable, and reliable information on companies' sustainability performance disclosed in their annual reports, specifically in sustainability statements (Primec, 2024a). For this purpose, the EU adopted legislation that made voluntary sustainability reporting mandatory. The legislative framework governing sustainability reporting consists of three key instruments. In addition to the Non-Financial Reporting Directive (NFRD) and its successor, the CSRD, this framework also includes Regulation (EU) 2019/2088 of the European Parliament and of the Council on sustainability-related disclosures in the financial services sector (Sustainable Finance Disclosure Regulation – SFDR) and the Taxonomy Regulation (European Parliament, 2020; Primec, 2025).

The initial legislative acts adopted at the EU level (NFRD, CSRD, SFDR) include only mandatory sustainability reporting obligations, while failing to address crucial issues related to companies' civil liability and directors' due diligence duties (Bohinc, 2023; Ferrarini, 2022). From this perspective, the CSDDD represents a turning point, as it is the first legislative instrument to intervene directly in company law. It imposes on companies operating within the EU internal market a due diligence obligation regarding adverse human rights and environmental impacts caused by their own operations or by those of their subsidiaries and business partners within their value chains.

3.1.1 Changing Geopolitical and Economic Context of EU Sustainability Regulation

The circumstances in which the CSRD and the CSDDD were drafted and adopted must be understood within the broader context of structural changes in the international environment, characterised in recent years by growing geopolitical instability, the transformation of global economic relations and increasing social pressures within developed economies. Global security conditions have gradually deteriorated, accompanied by a growing number of armed conflicts and an increasingly fragmented international environment (Institute for Economics and Peace, 2024). In this context, the Russian aggression against Ukraine has significantly reshaped the European security and economic landscape, particularly through rising energy prices affecting European companies (Lucian, 2024). At the same time, instability in the Middle East and escalating tensions among major global actors have further deepened uncertainty and reinforced the interconnection between economic, security and political interests.

In such circumstances, the EU faces a complex strategic position marked by economic interdependence with global markets and security dependence on the US, which complicates the development of a coherent, long-term, and stable foreign and economic policy. At the same time, globalisation processes continue to generate significant social pressures, particularly on the middle class, linked to rising living costs, income stagnation and structural changes in the labour market (OECD, 2019; Eurofound, 2023). These trends contribute to political polarisation and strengthen more protectionist and populist approaches, indirectly influencing debates on the regulatory burdens imposed on companies and their competitiveness.

Against this background, the EU nevertheless pursued an ambitious normative approach in the field of sustainable development, most visibly expressed in the European Green Deal of 2019, which served as a framework for the transition towards a climate-neutral economy (Schunz, 2022). However, the implementation of these objectives has increasingly come under pressure due to changing geopolitical and economic conditions. Growing security uncertainty, the restructuring of global trade flows and the increasing importance of strategic and industrial policies have gradually limited the space for the unilateral pursuit of ambitious environmental objectives. These developments have also affected perceptions of sustainability legislation. Due to differing approaches adopted by other major economies, particularly the US and Switzerland, increasing attention has been directed to the competitiveness of European companies, alongside concerns that sustainability reporting and due diligence obligations impose excessive or insufficiently coordinated burdens.

Institutional dynamics must also be considered. The CSDDD was adopted during the previous Commission mandate, whereas the new mandate, despite continuity in leadership, reflects a somewhat altered political and legislative orientation. In her inaugural address at the beginning of the second mandate in November 2024, the President of the European Commission announced amendments to several existing regulations and directives, with particular emphasis on simplification, rationalisation and greater clarity of the EU legal order (European Commission, 2024b).

3.1.2 The Impact of the Omnibus Simplification Package on the CSDDD and Its Proposed Amendments

The changed geopolitical and economic circumstances have therefore had a significant impact on EU sustainability regulation. The growing tension between environmental objectives and competitiveness is reflected in the gradual adjustment of the legislative approach, which places greater emphasis on feasibility and proportionality. This became particularly evident in 2025 through the so-called EU Competitiveness Compass (European Commission, 2025a). This new strategy is based on three priority objectives: closing the innovation gap, decarbonising the economy, and reducing dependencies, all of which are derived from Draghi's report on the future of European competitiveness. The Commission began implementing this strategy through the already mentioned omnibus package. Taken as a whole, the

Omnibus I and Omnibus II packages affect several legislative instruments, namely the CSRD, the CSDDD, the Taxonomy Regulation, Regulation (EU) 2023/956 establishing a Carbon Border Adjustment Mechanism (CBAM), Regulation (EU) 2021/523 establishing the InvestEU Programme and amending Regulation (EU) 2015/1017, Regulation (EU) 2015/1017 on the European Fund for Strategic Investments, Regulation (EU) 2021/1153 establishing the Connecting Europe Facility and Regulation (EU) 2021/695 establishing Horizon Europe, the Framework Programme for Research and Innovation.

Omnibus I introduces targeted mechanisms to simplify and rationalise the legal frameworks governing sustainability reporting under the CSRD and due diligence under the CSDDD. Its fundamental objective is to reduce the administrative costs borne by companies without diminishing the purpose of either directive or undermining the strategic objectives of the European Green Deal relating to a green and just transition.

Among the more significant innovations are expanded opportunities for voluntary disclosures under the EU Taxonomy framework, as well as adjusted reporting obligations, which could give companies with advanced sustainability strategies a competitive advantage in attracting investment.

Omnibus II is directed towards amendments to the InvestEU Regulation, which constitutes the Union's largest risk-sharing instrument for supporting priority investments within the Union. The amendments are intended to increase the programme's effectiveness, particularly through an expansion of the EU guarantee and the creation of provisioning mechanisms using returned funds from the European Fund for Strategic Investments (EFSI). The InvestEU and EFSI Regulations will also be simplified in order to reduce the frequency and scope of certain reporting obligations. Among other measures, an exemption is envisaged for small final recipients, such as SMEs, together with an adjusted application of certain rules, including the definition of SMEs for particular financial products, in accordance with the principle of proportionality. The objective of these amendments is to reduce the administrative burden imposed on implementing partners of the InvestEU Programme, as well as on financial intermediaries and final recipients, particularly SMEs, who are required to provide reporting data to the Commission and to apply the prescribed rules. As is evident, Omnibus II substantively focuses

on the simplification of investment programmes, primarily InvestEU and EFSI, while it does not address questions relating to sustainability reporting and governance. Accordingly, the following discussion focuses on Omnibus I, which substantively covers the subject matter of this project (Primec, 2025).

Following lengthy negotiations and considerable normative uncertainty during 2025 regarding the final scope and content of the proposed amendments, the Omnibus I package was adopted at the EU level and materialised in Directive (EU) 2026/470. The Directive was published on 26 February 2026 and entered into force on 18 March 2026, with a deadline for transposition into national legal orders set for 26 July 2028. At the same time, the application of certain obligations was postponed, reflecting a more gradual approach to implementing the adjusted regulatory framework (European Commission, 2026). At the CSDDD level, the amendments are most clearly reflected in the narrowing of the personal scope of application, which is now limited to the largest economic entities. The Directive applies to companies with at least 5,000 employees and at least EUR 1.5 billion in global net turnover, as well as to certain categories of third-country undertakings generating comparable turnover within the EU internal market. Such regulation represents a departure from the originally broader circle of obligated entities, although, as already emphasised, not necessarily a reduction in the regulatory framework's actual reach. Among the more significant amendments are the removal of the obligation to adopt climate transition plans and the abolition of a uniform civil liability regime harmonised at the EU level. As a consequence, the regulation of civil liability has been left to the Member States, raising questions about the uniformity of legal protection and the predictability of the law. Nevertheless, the right to compensation remains a central mechanism for ensuring the Directive's effectiveness. The sanctions framework has also been amended to introduce a limit on fines based on a company's global net turnover. The financial sector has retained a special position, as due diligence obligations do not fully encompass the core activities of financial institutions. Such a solution may create certain systemic gaps, particularly given that financial flows are a key lever for creating or preventing adverse human rights and environmental impacts.

In the field of sustainability reporting, the amendments primarily aim to rationalise obligations. The thresholds for applying the rules have been increased, the number of obligated entities reduced, certain sector-specific standards abolished, and

broader possibilities introduced for restricting the disclosure of information that could seriously affect the company's competitive position. Viewed comprehensively, the amendments introduced through the Omnibus I package do not constitute an abandonment of the fundamental objectives of sustainable corporate governance, but rather their normative adaptation to changing economic and geopolitical circumstances. At the same time, however, these amendments raise important legal questions concerning the effectiveness, uniformity and actual reach of the regulatory framework, particularly in relation to the individual due diligence mechanisms established under the CSDDD (Dadush & Schönfelder, 2026).

3.2 Transformation of Due Diligence into a Binding Legal Obligation

3.2.1 Due Diligence as a Non-Binding Standard

The concept of due diligence, from an etymological perspective, denotes reasonable or appropriate care and refers to a standard of conduct that must be observed under circumstances in order to avoid liability arising from negligence. In a broader sense, due diligence is generally understood as one of the fundamental mechanisms through which corporate responsibility is exercised (Hösli & Weber, 2022). Originally, the concept emerged from commercial and financial practice, where it was understood as a process of careful examination and risk assessment in the context of corporate transactions, particularly mergers and acquisitions. In this field, due diligence represented a comprehensive process of collecting, verifying and analysing information concerning a company's business operations, assets and legal position, to ensure informed decision-making and reduce the purchaser's commercial and legal exposure (Howson, 2003).

Over time, the concept expanded beyond its original field of application and evolved into a broader instrument of preventive risk management, encompassing the environmental and social aspects of business activities. This development was reflected in the establishment of environmental, social, and human rights impact assessments, which, in certain legal systems, became a prerequisite for the approval and implementation of large-scale projects (Graetz & Franks, 2013). The broader use of the concept of due diligence became established during the 1990s, when discussions of corporate responsibility for protecting human rights intensified following revelations of systemic abuses within global value chains, particularly in

the oil, mining, and textile sectors. The first attempt at a legal definition was the Draft Norms on the Responsibilities of Transnational Corporations (United Nations, 2003), which was ultimately not adopted due to opposition from economic interests. Nevertheless, it significantly influenced subsequent developments and laid the groundwork for the United Nations “Protect, Respect and Remedy” framework (2008), developed by John Ruggie. This framework established a systemic approach to the relationship between business activities and human rights, grounded in three fundamental pillars: the state's duty to protect rights, companies' responsibility to respect them, and individuals' right to effective legal protection. An important innovation of the second pillar was the definition of due diligence as the fundamental process for fulfilling corporate responsibility, namely a set of procedures through which companies identify, prevent and manage adverse human rights impacts throughout the entire value chain (United Nations, 2010).

This approach was subsequently incorporated into the UNGPs, which defined due diligence as a global standard of responsible business conduct (United Nations, 2011). Further development and concretisation of these principles were provided by the OECD, which, through its due diligence guidance for responsible business conduct, established a practical, internationally coordinated framework for their implementation. The guidelines are based on an approach to the prevention, management, and remediation of the adverse impacts of economic activities on human rights, the environment, and society, while also promoting transparent and sustainable business practices that extend beyond mere compliance with legal obligations and strengthen stakeholder trust (OECD, 2018, 2023).

The fundamental approach advanced by the CSDDD, together with its earlier versions prepared within the framework of the European Commission, is based on the international instruments concerning responsible business conduct and transposes them into a binding normative framework of EU law (Schmidt, 2024).

As can be observed, the concept of due diligence developed through political guidance and became firmly established in the practice of all stakeholders. At the same time, stakeholders emphasised the need to preserve the normative clarity and substantive consistency of due diligence concepts, since replacing them with substantively looser or terminologically less precise expressions could weaken their legal significance and effectiveness. To establish greater conceptual and

terminological coherence in international legal discourse, Rühmkorf and Walker advocate the use of the term 'due diligence' as a recognised, generally accepted legal concept (European Commission, 2020). In substantive terms, the concept of due diligence relates to existing standards of care within the framework of tort law and with corresponding standards in civil law systems. However, it exceeds the traditional framework of duties of care, particularly in terms of the scope and enforcement of obligations. This obligation is not confined solely to private law liability, such as claims for damages. However, it may also encompass public enforcement mechanisms, including the imposition of sanctions or fines for failure to adequately implement due diligence obligations (Hösli & Weber, 2022).

The CSDDD significantly contributes to the harmonisation of European legislation, as it is fundamentally based on internationally established due diligence standards, particularly the UNGPs (United Nations, 2022) and the OECD Guidelines for Multinational Enterprises (OECD, 2023). These instruments constitute the principal normative framework that has gradually shaped expectations concerning corporate responsibility within global supply chains over the past decade. Through their integration, the CSDDD transcends narrower national or sector-specific approaches and establishes a legally binding system that ensures uniform conditions within the EU internal market while preventing distortions of competition among companies operating in different legal environments.

3.2.2 Due Diligence as a Binding Legal Obligation for Companies

3.2.2.1 The Introduction of the CSDDD

At the level of EU law, the due diligence obligation in sustainability matters is defined as the obligation of companies to identify and address actual and potential adverse impacts on human rights and the environment arising from their own operations, the operations of subsidiaries and, where relevant in relation to the chain of activities, also the operations of business partners (European Commission, n.d.).

The concept of due diligence is founded upon international standards of responsible business conduct, primarily within the framework of the United Nations and the OECD. The UNGPs define due diligence as a process through which companies identify, prevent and mitigate adverse human rights impacts and account because

such impacts are addressed. Compared with the UNGPs, the OECD Due Diligence Guidance for Responsible Business Conduct extends the concept of due diligence to environmental protection as well. It defines it as a structured and ongoing process through which companies identify, prevent, mitigate, and address actual and potential adverse impacts arising from their own operations, supply chains, and other business relationships.

It is evident that the development of laws and other regulatory frameworks significantly influences how companies respond to human rights due diligence (HRDD). HRDD is comparable to due diligence in other legal contexts in that it constitutes an objective standard based on which a defendant may demonstrate compliance with a particular duty of care. It involves a contextual assessment that considers what a reasonable or prudent company knew or ought to have known under the circumstances. However, HRDD differs from other forms of due diligence in that it focuses on the impacts of corporate activities on human rights rather than solely on business risks (McCorquodale et al., 2017).

From the foregoing, it may be inferred that due diligence has become embedded as a constitutive element of modern corporate governance directed towards responsible and sustainable business conduct. As will be demonstrated in the following sections, the substantive understanding of due diligence does not merely concern compliance with minimum legal requirements, but rather encompasses systematic, risk-based and long-term management of impacts on human rights, the environment and other legally protected interests. Due diligence thereby becomes an autonomous obligation of companies, the non-fulfilment or breach of which may result in sanctions, including fines and civil liability.

The new obligation introduced by the CSDDD for certain categories of companies is examined in greater detail below, including the principal aspects of Omnibus I.

3.2.2.2 Due Diligence Obligation

Companies are required to identify and appropriately address actual and potential adverse impacts on human rights and the environment arising from their own operations, the operations of their subsidiaries and the operations of their business partners within the chain of activities of those companies (Article 1(1)(a) CSDDD).

The initial Omnibus I proposal envisaged a narrowing of the material scope of due diligence to direct business partners and to partners operating “upstream” within the value chain, namely suppliers. However, this solution was ultimately abandoned in the final text of the amended CSDDD, with the consequence that the concept of a business partner, as defined in the original text of the Directive, remains unchanged, as follows from Article 1(1)(f) CSDDD. The original objective of the Omnibus I proposal, to reduce administrative and financial burdens for obligated companies, is therefore pursued through other legislative adjustments. Among the more significant measures are the narrowing of the personal scope of application, namely the reduction in the number of obligated entities, the removal of the obligation to adopt and implement climate transition plans, and the abolition of a uniform civil liability regime for breaches of due diligence obligations. Certain simplifications, however, are also reflected in the material scope of due diligence obligations, which will be examined further below.

3.2.2.2.1 Identification and Assessment of Adverse Impacts

In accordance with the provisions of the CSDDD, the substance of due diligence is to identify and mitigate adverse human rights and environmental impacts arising from companies' activities. An adverse human rights impact is understood as an impact resulting from the violation of specific human rights exhaustively listed and adapted to the particular context of corporate conduct, as set out in Part I, Section 1 of the Annex to the CSDDD, as well as rights deriving from specifically enumerated international instruments pursuant to Part I, Section 2 of the Annex.

These additional rights, such as the right to liberty and security of person under Article 9 of the International Covenant on Civil and Political Rights (ICCPR), are included provided that the company is in fact capable of impairing them, that the interference may affect a legally protected interest, and that the possibility of such interference could reasonably have been foreseen, as follows from Article 3(1)(c) CSDDD. Similarly, an adverse environmental impact is defined as an impact resulting from the violation of prohibitions and obligations established in international environmental instruments referred to in the Annex to the CSDDD, particularly within the framework of Part I, Sections 15 and 16, as well as Part II of the Annex. Such an impact also encompasses measurable environmental degradation

that interferes with human rights, especially the rights to food, water, health, and the use of land.

Although the Annex constitutes a relatively extensive catalogue, its exhaustive limitation to expressly enumerated rights and instruments, together with the exclusion of documents such as the Universal Declaration of Human Rights, departs from the broader understanding of internationally recognised human rights underlying the UNGPs. Furthermore, certain rights, such as the rights to food or health, are formulated from a corporate perspective, which does not fully reflect their broader content under international human rights standards.

Attention should also be drawn to the terminological aspect. The use of terms such as “abuse” or “violation” carries connotations associated with the responsibility of states under international human rights law or environmental law. Such terminology may unintentionally raise the threshold for determining when an impact is sufficiently serious to be considered relevant within the framework of corporate due diligence obligations, thereby affecting the scope and intensity of the preventive obligations imposed on companies (Bueno et al., 2024).

The CSDDD's approach is risk-based and requires companies to prioritise due diligence in areas of activity where the likelihood and severity of adverse impacts are greatest.

The identification and assessment process is structured in two phases. First, companies conduct a preliminary assessment based on reasonably available information, considering risks connected to business partners, geographic and institutional conditions, and the relevant sector or activity. On this basis, they identify actual and potential adverse impacts arising from their own operations, subsidiaries and business partners within the chain of activities. Second, companies must carry out an in-depth assessment in areas presenting the highest level of risk, which serves as the basis for subsequent preventive or corrective measures (Article 8(1) and (2) CSDDD).

3.2.2.2.2 Proportionality in Information Gathering and the Prioritisation of Risks

The framework established under the CSDDD requires due diligence to be carried out in a proportionate and targeted manner, as reflected in the design of information requests addressed to business partners. Companies may request from business partners only the information genuinely necessary for conducting an in-depth assessment of adverse impacts. For partners with fewer than 5,000 employees, such requests are permissible only when the necessary information cannot reasonably be obtained through other means. Where relevant information may be obtained from several business partners, companies must, where reasonable, direct their requests primarily to the partner or partners for whom the likelihood of adverse impacts is greatest. In situations where adverse impacts across different areas are equally likely or equally severe, priority is given to areas involving direct business partners.

In identifying and assessing adverse impacts, companies may rely on a broad range of appropriate sources, including both quantitative and qualitative data. These include independent reports, digital tools, industry and multi-stakeholder initiatives, as well as information obtained through notification mechanisms and complaints procedures. Such an approach enables effective due diligence while simultaneously limiting unnecessary administrative burdens for smaller partners in the chain of activities (Article 8(3) CSDDD).

Where not all identified risks can be addressed simultaneously, companies must prioritise those adverse impacts that are the most severe and most likely to occur, considering their scale, gravity and possible irreversibility. Less severe and less probable risks may be addressed subsequently. The mere fact that a less significant adverse impact has not been addressed does not in itself expose the company to penalties under Article 27 (Article 9 CSDDD).

3.2.2.3 The Content of Individual Due Diligence Actions

The CSDDD derives due diligence as a comprehensive process from established international standards, particularly UN and OECD instruments. These standards define six core phases: integrating responsible business conduct into corporate policies; identifying and assessing risks; preventing or mitigating adverse impacts;

monitoring effectiveness; ensuring transparency; and providing remediation together with complaint mechanisms. The CSDDD follows these phases while simultaneously developing them in greater normative detail through Articles 7 to 16, by placing individual procedural elements of due diligence within a legally binding framework and adapting them to the particularities of corporate operations. In this manner, the general principles contained in international standards are transformed into precise obligations imposed on obligated entities.

Since certain procedural elements, particularly the identification and assessment of actual and potential adverse impacts, have already been addressed in the previous subsection, the following discussion focuses on the remaining elements constituting the substance of due diligence.

3.2.2.3.1 Integration of Due Diligence into Company Policies and Risk Management Systems

Under the CSDDD, due diligence must be integrated into the company's internal governance structure as a constituent element. Accordingly, the company is first required to adopt a due diligence policy, which must subsequently be incorporated into its internal policies, codes of conduct and risk management systems.

Companies must implement a comprehensive due diligence process encompassing the identification, prevention, mitigation and remediation of adverse impacts, supported by stakeholder engagement and an effective complaint mechanism. The Directive also regulates information exchange, the protection of trade secrets, and obligations concerning documentation and the retention of evidence relating to due diligence activities (Article 7 CSDDD).

3.2.2.3.2 Prevention of Potential Adverse Impacts

Preventing potential adverse impacts is the central preventive element of due diligence, requiring companies to adopt appropriate and proportionate measures promptly before harm materialises. The selection of such measures depends on the nature of the identified risk, its severity, and the company's actual ability to influence the conduct of entities within its chain of activities. Where necessary, companies are required to:

- adopt and implement prevention action plans with measurable indicators,
- obtain contractual assurances from business partners regarding compliance with codes of conduct and preventive measures,
- undertake organisational, technical or financial adjustments, including changes to business strategies or practices,
- provide targeted and proportionate support to SMEs, including training or financial assistance,
- cooperate with other entities through industry or multi-stakeholder initiatives.

Attention is devoted to SMEs. Where companies obtain contractual assurances from SMEs or conclude agreements with them, the contractual terms applied must be fair, reasonable and non-discriminatory. As a rule, the costs of compliance verification for SMEs are borne by the company itself, as provided for in Article 10 of the CSDDD.

3.2.2.3.2.1 Suspension of Business Relationships as a Last Resort

In situations where a company, despite having adopted appropriate measures, is unable to prevent or adequately mitigate an adverse impact, it is required to resort to measures of last resort relating to the adjustment of its relationship with the relevant business partner for the duration of the impact.

This means that the company must refrain from entering into new business relationships or extending existing ones and may, where permitted under applicable law, temporarily suspend or terminate the relationship in relation to the activities concerned. At the same time, the company is required, without undue delay, to develop and implement an enhanced prevention action plan, the effectiveness of which may reasonably be expected. The mere continuation of the business relationship under such circumstances does not in itself constitute an independent basis for sanctions or civil liability. Prior to deciding on a temporary suspension, the company must also assess the consequences of such a measure. Where the suspension would result in manifestly more severe adverse consequences than the already existing impact, the company is not required to adopt such a measure, although it must properly substantiate its decision. Irrespective of this, the company remains under an obligation to monitor adverse impacts continuously and regularly

review the appropriateness of the measures adopted, as provided for in Article 10(7) CSDDD. The same approach also applies to measures adopted by the company to eliminate actual adverse impacts, as provided for in Article 11 of the CSDDD.

3.2.2.3.3 Addressing Actual Adverse Impacts

Where an adverse impact has already materialised, due diligence extends beyond its purely preventive dimension. It requires the company to adopt measures to end or mitigate the impact or otherwise remediate its consequences. Such measures must, in both substance and intensity, be adapted to the nature of the specific impact and directed towards the most effective possible restoration of a legally and factually acceptable situation.

In selecting appropriate measures, account must be taken of the entity responsible for causing the impact, namely, whether the impact resulted from the company's conduct, from joint conduct involving a business partner, or exclusively from the partner's conduct. At the same time, consideration must also be given to the level within the chain of activities at which the impact arose, whether at the level of a subsidiary, a direct business partner or an indirect business partner, as well as to the actual ability of the company to influence the conduct of the entity responsible. Where the impact cannot be brought to an immediate end, the company is at least required to minimise its extent as much as possible. To addressing adverse impacts, the company must adopt one or more of the following measures:

- neutralise or minimise the impact, considering its severity and the company's degree of involvement,
- develop and implement a corrective action plan containing clearly defined timelines and measurable indicators,
- obtain contractual assurances from business partners regarding compliance with the code of conduct and the adopted measures, together with appropriate verification mechanisms, including mechanisms involving independent third parties,
- undertake the necessary organisational, technical or financial adjustments and, where appropriate, modify business strategies,

- provide targeted and proportionate support to SMEs where necessary in order to achieve compliance,
- where appropriate, cooperate with other entities,
- provide remediation to affected persons.

Where an actual adverse impact cannot be ended or adequately minimised despite the measures adopted, the company is required, as a measure of last resort, temporarily to suspend or terminate the business relationship with the relevant partner, while simultaneously implementing an enhanced corrective action plan where its effectiveness may reasonably be expected. For as long as such a plan is reasonably assessed as effective, the mere continuation of the business relationship does not constitute a basis for imposing penalties under Article 27 or for liability under Article 29, as follows from Article 11 CSDDD.

3.2.2.3.4 Remediation of Adverse Impacts

Where an adverse impact has already materialised, the company is required either to provide, or at least participate in providing, appropriate remediation for the harm caused. Where the actual adverse impact has been caused exclusively by a business partner, the company may engage in voluntary remediation while using its ability to influence the partner's conduct to secure appropriate compensation. Such an obligation follows from Article 12 CSDDD.

Remedial measures may encompass various forms of redress for the consequences of harm, including the restoration of the previous situation, the provision of financial or non-financial compensation, as well as reimbursement of costs incurred by public authorities in connection with the implementation of corrective measures, as provided for in Recital 58 CSDDD.

3.2.2.3.5 Stakeholder Engagement

Effective implementation of due diligence presupposes appropriate stakeholder engagement, since, without their participation, a company often cannot comprehensively identify the actual or potential adverse impacts of its operations. Stakeholder engagement, therefore, does not represent merely a supplementary

element, but rather an important methodological and substantive basis for the development of appropriate, proportionate and genuinely effective measures. Companies are required to ensure effective and informed engagement with stakeholders throughout all key stages of due diligence, particularly in identifying adverse impacts and developing preventive, corrective, and remedial measures.

In this context, stakeholders must be provided with access to appropriate information, the opportunity to obtain additional explanations, and protection against potential retaliatory measures. Where direct engagement is not feasible, experts may be involved. Although compliance with these obligations may also be organised through industry-based or multi-stakeholder initiatives, such an approach does not replace engagement with employees and their representatives in accordance with labour law rules, as provided for in Article 13 CSDDD.

3.2.2.3.6 Complaints Procedure

The establishment of complaint mechanisms represents an important procedural aspect of due diligence, as it enables the early detection of adverse impacts and establishes a formalised avenue for their consideration. Their effectiveness largely depends on the degree of accessibility, transparency, and their capacity to enable affected persons and other entitled entities to assert their claims in a timely and effective manner. Complaints may be submitted by affected persons or their legal representatives, including civil society organisations, trade unions and workers' representatives, as well as organisations with relevant expertise in environmental protection.

The procedure itself must be publicly accessible, predictable, and designed to ensure protection against retaliatory measures, including the possibility of anonymous or confidential complaint submissions. In the event of a substantiated complaint, the adverse impact is deemed to have been established, thereby triggering the company's obligation to adopt appropriate preventive, corrective and remedial measures. In addition, companies are also required to establish a notification mechanism concerning risks or violations, which may operate independently or within collective or industry-based systems. Importantly, the submission of a complaint or notification does not constitute a condition for access to judicial or other non-judicial remedies, as follows from Article 14 CSDDD.

3.2.2.3.7 Monitoring the Effectiveness of Due Diligence Measures

By its nature, due diligence is not a one-off action but a continuous, cyclical process that requires companies to monitor the effectiveness of the measures adopted and their due diligence policy. Such monitoring enables an assessment of whether the adopted preventive and corrective measures genuinely contribute to reducing identified risks and whether they require supplementation, adjustment, or replacement with more effective solutions.

Under Article 15 CSDDD, companies must regularly assess the effectiveness of measures adopted in relation to their own operations, subsidiaries and relevant business partners. Such assessments must be carried out following substantial changes in circumstances and otherwise at least every five years, particularly where doubts arise regarding the effectiveness of existing measures or where new risks emerge. Based on these assessments, companies must, where appropriate, adapt their due diligence policies and update the measures adopted.

3.2.2.3.8 Communication and Transparency

Transparency represents one of the fundamental preconditions for the effective implementation of due diligence, as it enables external scrutiny of corporate conduct and strengthens corporate accountability towards affected stakeholders, the market and the wider public. The obligation to communicate or report, therefore, does not operate merely as a formal requirement but rather as an integral part of a system that enables an understanding of the policies adopted, the risks identified, and the measures implemented.

For this purpose, companies are required to publish annual reports on matters governed by the Directive, which must be made available on their websites. The report must be prepared in an appropriate official language of the EU used in the state of the supervisory authority and, where relevant, also in a language commonly used in international business. Publication must be ensured within a reasonable period, and no later than 12 months after the end of the financial year or the publication of the annual financial statements, where the company voluntarily reports in accordance with sustainability reporting rules. For third-country companies, an additional requirement applies: the report must also include

information on their authorised representative within the EU. The reporting obligation does not, however, apply to companies already reporting on sustainability matters under the CSRD, since, in such cases, the relevant requirements are deemed to be fulfilled within the existing sustainability reporting framework, as follows from Article 16 CSDDD.

4 Results and Discussion

The analysis confirms that the amendments introduced by the Omnibus I package primarily affect the scope and operationalisation of obligations, while the fundamental structure of due diligence remains unchanged. Even in its amended form, the CSDDD retains a procedural model based on systematic risk management, in which the normative weight lies not in individual measures as such, but rather in the coherence and effectiveness of the company's conduct system. The central issue, therefore, becomes how companies should organise their internal processes to identify and address adverse impacts arising within complex business relationships. A more detailed examination of the framework's elements demonstrates that the CSDDD establishes a structured regime that goes beyond the traditional understanding of legal obligations as static rules of conduct. Due diligence is shaped as a dynamic and adaptable standard, the content of which is determined in light of the specific circumstances of each case, particularly regarding the severity and likelihood of adverse impacts, and the company's actual ability to influence the conduct of other entities. Such a structure raises important questions about legal certainty and the criteria for assessment, since the focus of evaluation shifts to the appropriateness of corporate conduct in specific situations.

The CSDDD also significantly influences the further development of EU corporate law and opens a new developmental dimension within the field. The Directive increasingly connects corporate law with the protection of a broader range of stakeholders, as well as with human rights and environmental considerations, thereby moving beyond its more traditional understanding. In this way, corporate law is gradually adapting to contemporary social and economic expectations and acquiring a more pronounced sustainability dimension. Although the future development of this transformation will largely depend on the evolution of the broader legal and institutional framework, the CSDDD has undoubtedly marked a new direction in the development of EU corporate law.

Within this framework, the role of relationships within the chain of activities becomes particularly significant. Although the thresholds for applying the Directive have been substantially increased following the reform, due diligence obligations remain designed to extend beyond the boundaries of a single legal entity. This means that standards of conduct are also shaped and implemented through contractual relationships, business practices and expectations among economic actors. Such a mechanism creates a diffuse regulatory effect that is not linked solely to the formal status of an obligated entity, but rather to its actual participation in economic flows. A further aspect highlighted by the analysis concerns the relationship between the normative framework and its enforcement. Amendments relating to liability, particularly the abandonment of a uniform European regime, increase the significance of national legal systems. Therefore, the emphasis shifts from harmonisation to concretisation, where Member States, through legislative and institutional solutions, will determine how intensively and effectively due diligence obligations will be implemented. This raises questions concerning potential divergences among legal systems and their impact on legal certainty and the unity of the internal market.

Within the Slovenian legal framework, this context raises the question of the relationship between the new requirements and the existing ZGD-1 normative framework, which, as the fundamental statute of Slovenian corporate law, still primarily regulates the disclosure dimension of sustainability. Such a structure reflects the previous development of EU law, which was predominantly directed towards ensuring corporate transparency, whereas the CSDDD introduces a significantly broader and substantively more demanding regime of conduct. This regime extends beyond mere reporting obligations and encompasses the organisation of internal processes, risk management, relationships within the chain of activities and various forms of legal liability. The difference in normative logic raises the question of whether the existing system can be adequately upgraded through limited amendments or whether a more comprehensive legislative solution should be considered to ensure transparent and systematic regulation of this field. From the perspective of the future development of the Slovenian legal order, the key issue will above all be how to ensure the effective integration of these obligations while simultaneously preserving the internal coherence of the legal system. A particular challenge lies in the relationship between traditional institutes of corporate law, especially the duties of administrative, management and supervisory bodies, and

the new due diligence obligations, which broaden their substantive framework. Equally important will be the question of the institutional framework for supervision and enforcement, including the relationship between administrative and civil law mechanisms, as well as the development of clear criteria for assessing the appropriateness of corporate conduct in practice.

In a broader sense, the developments analysed demonstrate the gradual transformation of EU corporate law, within which sustainability considerations are increasingly becoming an integral element of legally relevant corporate conduct. Even after the reform, the CSDDD continues to operate as a normative framework that encourages the integration of these considerations into corporate decision-making and governance processes, while simultaneously raising unresolved questions about its actual effectiveness. The answer to these questions will largely depend on the specific solutions adopted at the level of the Member States, their legislative and drafting quality, and the further development of administrative and judicial practice. It is precisely this implementation dimension that constitutes the key point of departure for further discussion and research, particularly in the context of the Slovenian legal system.

5 Conclusion

The amendments introduced through the omnibus reform confirm that, even within a narrowed regulatory framework, the due diligence obligation remains a key legal instrument of responsible, sustainability-oriented corporate governance. It does not merely concern formal compliance with normative requirements, but rather constitutes a structured, risk-based process through which companies identify, prevent, mitigate, and remedy adverse impacts on human rights and the environment. In this way, due diligence extends beyond the traditional understanding of regulatory obligations and becomes embedded within the core of legally relevant corporate conduct.

The substantive reach of this obligation is reflected in the requirement to establish reasonable, effective and appropriately tailored procedures, the omission or inadequate implementation of which may give rise both to administrative measures and to civil liability. Due diligence, therefore, increasingly emerges as a normatively binding criterion for assessing corporate conduct and legal responsibility.

Within this framework, Directive (EU) 2024/1760 establishes a dual system of legal consequences. On the one hand, it provides for administrative sanctions for failures in establishing and implementing a due diligence system, without requiring proof of actual damage or the materialisation of an adverse impact. On the other hand, it establishes a framework for civil liability, while leaving the formulation of specific rules to national legal systems. Liability arises upon fulfilment of the classical conditions, particularly the existence of damage and a causal link between the breach of due diligence obligations and the resulting harmful outcome.

Because of this combination of administrative supervision and potential civil liability, understanding the substance and scope of due diligence obligations is a key element of legal certainty for companies. Due diligence is therefore not exhausted through the mere formal adoption of internal rules but requires their actual effectiveness and adaptation to specific risks.

On this basis, it is possible to formulate an answer to the central research question. Due diligence in the field of corporate sustainability, as regulated by the reformed CSDDD, constitutes a transformative legal standard within EU corporate law. However, this transformation is evolutionary rather than discontinuous. Its essential novelty lies in the normative transformation of existing concepts of corporate responsibility.

First, due diligence introduces an obligation of procedural conduct, shifting the centre of gravity of legal responsibility from ex post sanctioning of damage towards the ex ante organisation of business processes. Companies are no longer merely addressees of prohibitions against causing harm, but become bearers of duties of active risk management, which represents a significant shift in the structure of corporate law.

Second, due diligence influences the substantive understanding of the duties of administrative, management and supervisory bodies. Although the Directive does not directly interfere with national concepts of fiduciary duties, it effectively broadens their substantive framework by requiring consideration of the interests of a broader range of stakeholders and the long-term impacts of corporate activities. In this way, the traditionally shareholder-oriented understanding of corporate interest is gradually supplemented by elements of sustainability responsibility.

Third, due diligence establishes a multi-layered regulatory mechanism that connects internal corporate processes, administrative supervision, and civil law sanctions. This integrated approach reinforces its character as an operational legal standard that directly influences corporate organisation, decision-making, and supervision.

At the same time, however, the reform also reveals certain limitations of this standard. The narrowing of the circle of obligated entities and the emphasis placed on proportionality reflect a normative compromise that reduces its universal reach, although without diminishing its systemic significance.

In conclusion, due diligence in corporate sustainability constitutes a qualitative advancement of EU corporate law. It does not introduce an entirely new legal concept but rather transforms existing legal structures within which sustainability considerations increasingly become a constitutive element of legally relevant corporate conduct. Its actual effectiveness will depend primarily upon consistent implementation within national legal systems and upon the development of judicial and administrative practice that will give this standard concrete substantive meaning.

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Summary

This article examines the evolving role of corporate sustainability due diligence within EU company law, with particular focus on the implications of the Omnibus I reform of the Corporate Sustainability Due Diligence Directive (CSDDD). The analysis shows that, despite regulatory simplifications and a narrower scope of application, the core structure of due diligence remains intact as a risk-based, continuous and process-oriented obligation. The reform shifts emphasis toward proportionality and

implementation, increasing the importance of national legal frameworks and institutional design. The article argues that due diligence functions as an emerging legal standard of corporate governance, reshaping directors' responsibilities and integrating sustainability considerations into corporate decision-making, while leaving open questions regarding legal certainty, coherence and effective enforcement across Member States.

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INTERNATIONALIZATION STRATEGY AS SUSTAINABLE GOVERNANCE: NAVIGATING ESG AND AI TRANSFORMATION

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Internationalization in higher education is increasingly becoming a component of sustainable university governance in a period of rapid technological, societal, and geopolitical transformation. Rather than being understood primarily through mobility and partnership expansion, it needs to be approached as a strategic and value-based domain of institutional management. Internationalization is shaped not only by new globalization pressures, but also by European Union priorities, transnational project cooperation, sustainability expectations, and AI-driven digital transformation. These developments point to a broader shift from activity-based understandings of internationalization to governance-based approaches. Particular attention is given to more inclusive, equitable, environmentally responsible, and strategically coordinated forms of international engagement through alliances, as well as to the opportunities and governance risks associated with digitalization and artificial intelligence. The changing role of international offices is examined in this context through a brief practice-based reflection, highlighting their repositioning from administrative support units to strategic actors contributing to sustainable institutional development.

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1 Introduction

Internationalization in higher education can no longer be understood primarily through mobility, recruitment, and partnership expansion. These dimensions remain important, but they are no longer sufficient for capturing the full meaning of international engagement in a rapidly changing institutional environment. Universities now operate under the combined pressures of intensified global competition, geopolitical uncertainty, sustainability expectations, digital transformation, demographic change, and growing demands for inclusion and accountability. In this setting, internationalization is no longer simply an outward-facing set of activities; it increasingly becomes a question of how institutions define priorities, allocate resources, manage risk, and align international engagement with their academic mission and public role. This fundamental shift necessitates a re-evaluation of traditional approaches, moving towards a more strategic and integrated understanding of internationalization within the broader framework of university governance, where international engagement is not an "add-on" but a core institutional function.

This shift is reinforced by contemporary European policy. The European Strategy for Universities (European Commission, 2022) explicitly positions universities as key actors in building sustainable and resilient societies and economies, emphasizing their crucial role in addressing global challenges and fostering European values. Concurrently, the Erasmus+ programme (2026) no longer frames international engagement only through mobility, but links it intrinsically to inclusion and diversity, digital transformation, and environmental responsibility, reflecting a holistic approach to European higher education development. The Council of the European Union (2024) has simultaneously reaffirmed the continuing importance of mobility by setting a target that at least 23% of higher education graduates should have a learning mobility experience by 2030, while also aiming for at least 20% of learning mobility participants across the EU to be people with fewer opportunities by 2027. This dual focus underscores that mobility remains central, but it is increasingly embedded in a broader governance framework concerned with quality, fairness, and long-term value, moving beyond mere quantitative metrics to encompass qualitative impact and equitable access.

A similar development is visible in OECD (2025) thinking on transnational collaboration, which emphasizes that international cooperation increasingly depends on institutional capacity, regulatory compatibility, funding incentives, and cross-government coordination rather than on academic goodwill alone. This perspective highlights the complex interplay of national policies and institutional frameworks that shape effective international partnerships, where success is predicated on "policy coherence" and "regulatory interoperability." At the same time, UNESCO's (2023) guidance on generative artificial intelligence in education and research makes clear that digital transformation is not simply a matter of adopting tools. It requires policy capacity, human-centred governance, and deliberate institutional judgment to navigate the ethical and pedagogical implications of AI. Taken together, these developments suggest that the most important contemporary question is no longer how international a university appears, but how intelligently and responsibly it governs internationalization, ensuring that global engagement serves institutional mission and societal good in a sustainable manner.

This paper therefore makes a conceptual and practice-based contribution. It does not claim empirical validation in a statistical sense. Rather it develops a policy-informed conceptual synthesis and uses structured profession reflection from institutional practice to illustrate how the governance turn materializes in university management. Its original contribution is to connect three debates that are often treated separately: quality-oriented internationalization, ESG-oriented sustainable governance and AI-enabled institutional transformation. The discussion proceeds in seven steps. It first traces the move from internationalization as activity to internationalization as governance. It then shows that this shift is visible not only in mobility policies but also in European Universities alliances and project-based forms of cooperation. It next examines internationalization through an ESG lens, discusses the opportunities and risks associated with AI and digital transformation, and considers the changing role of international offices. Building on these strands, it proposes a framework for sustainable internationalization governance and concludes with a short reflection informed by institutional practice.

2 From Internationalization as Mobility to Internationalization as Governance

For a long time, the dominant grammar of internationalization was activity-based. Universities often evaluated success through visible and countable indicators: the number of incoming and outgoing students, the volume of agreements signed, the growth of English-taught programmes, the expansion of international recruitment, or the number of visiting professors and international events. This model had obvious advantages. It made internationalization measurable, communicable, and politically attractive. It also corresponded to a period in which internationalization was closely associated with openness, competitiveness, prestige, and institutional visibility, as evidenced by the IAU (2024) 6th Global Survey. However, this quantitative focus often overlooked the deeper strategic implications and qualitative outcomes of international engagement, leading to what some critics call "symbolic internationalization."

Yet this activity-based model is increasingly inadequate. It does not tell us whether international engagement is strategically aligned with the university's academic profile, whether it benefits the wider community of students and staff, whether partnerships are reciprocal and meaningful, or whether the institution is building long-term capacity through its international choices. A university may be highly active internationally and still be strategically fragmented, socially selective, environmentally inconsistent, or overly reliant on symbolic cooperation. In that sense, counting internationalization is not the same as governing it well. Hans de Wit's (2020) call for a more ethical and qualitative approach is particularly relevant here, because it challenges the long-standing tendency to equate internationalization with volume, visibility, and market-oriented expansion, advocating instead for a focus on genuine impact and responsible engagement.

A broader and more purposive understanding of internationalization is already embedded in the influential definition adopted by the International Association of Universities (IAU, accessed 2026), which describes internationalization as the intentional process of integrating an international, intercultural, or global dimension into the purpose, functions, and delivery of post-secondary education in order to enhance the quality of education and research for all students and staff and to make a meaningful contribution to society. This definition matters because it shifts the

discussion from activity to intentionality, from expansion to purpose, and from external visibility to institutional quality and societal value. It is therefore fundamentally governance-oriented, even if it is not always used that way in practice, emphasizing the strategic integration of international dimensions rather than their superficial addition.

The same direction can be seen in the idea of comprehensive internationalization associated with Hudzik (2015), which emphasizes that internationalization should not be confined to a specialist office or a limited set of mobility activities, but should be integrated across teaching, research, service, and leadership. Once internationalization is understood in this way, it becomes inseparable from institutional strategy and organizational design. The issue is no longer whether a university has international activity, but whether internationalization is embedded in decision-making, connected to core academic priorities, and supported by institutional capacities that make it sustainable rather than episodic, ensuring a coherent and impactful approach that permeates the entire institutional culture.

Recent OECD (2025) analysis deepens this governance perspective still further. It stresses that transnational collaboration depends on interacting policy fields such as migration, quality assurance, funding, research policy, and institutional incentives, and recommends stronger institutional capacity, support for diverse forms of engagement, and greater policy coherence. This is a crucial insight. It means that internationalization is not simply an arena in which universities act; it is also an arena in which universities are shaped by external frameworks and must respond through internal coordination and strategic choice. The central shift, then, is from seeing internationalization as institutional expansion to seeing it as institutional steering, where strategic foresight and adaptive governance are paramount in navigating a complex and often contradictory global policy landscape.

3 Beyond Mobility: European Universities and Project-Based Cooperation

The governance turn becomes even clearer when one looks beyond mobility itself. Contemporary internationalization increasingly takes place through deeper, longer-term, and more structurally demanding forms of transnational cooperation. The European Universities initiative is perhaps the clearest expression of this shift.

According to the European Education Area (accessed 2026), the initiative now encompasses 73 alliances with almost 650 higher education institutions across Europe. These alliances are presented not as simple exchange networks, but as strategic frameworks for deeper and more sustainable cooperation, fostering integrated curricula, joint degrees, and shared research agendas that challenge traditional institutional boundaries.

This is an important qualitative change. In a classic bilateral model, internationalization often revolved around relatively discrete activities: exchanges, visits, memoranda, occasional joint events. By contrast, alliance-based cooperation presupposes shared planning, joint agendas, stronger organizational interoperability, and the gradual building of trust and capacity across institutions. It requires coordination not only between international offices, but also across faculties, research units, support services, and leadership structures. Internationalization here is no longer a peripheral activity. It becomes part of how a university organizes itself in relation to others, demanding a fundamental rethinking of institutional structures, legal frameworks, and administrative processes to enable "seamless" transnational cooperation.

A similar logic applies to project-based cooperation. Much contemporary internationalization unfolds through grant consortia, thematic partnerships, research collaborations, innovation ecosystems, and capacity-building projects. These activities are not secondary to mobility; in many institutions they increasingly define the most strategically consequential forms of international engagement. Project cooperation is governance-intensive because it requires partner selection, internal coordination, compliance capacity, timeline discipline, reporting quality, and continuity beyond one-off contacts. It also often generates spillovers into curriculum development, research networks, staff development, and institutional positioning. For that reason, project cooperation should not be viewed as an add-on to internationalization, but as one of its most significant contemporary manifestations, requiring sophisticated management and strategic oversight to ensure that project outputs are integrated into long-term institutional development.

OECD's (2025) emphasis on supporting diverse forms of transnational engagement is particularly useful here, because it highlights that internationalization can no longer be captured adequately by mobility indicators alone. If universities define

their international success too narrowly through mobility numbers, they risk overlooking where the most demanding governance challenges and the most valuable long-term opportunities actually lie. Building a strong consortium, aligning project pipelines with institutional priorities, or participating meaningfully in a transnational alliance often requires more strategic judgment than processing individual mobility flows. That does not reduce the importance of mobility; rather, it situates mobility within a much wider ecosystem of international cooperation, where its value is amplified through strategic integration and multi-level partnership development.

4 Internationalization through an ESG Lens

If internationalization is increasingly a matter of governance, the next question is according to what principles it should be governed. One useful answer is provided by an ESG lens. In the higher education context, ESG should not be treated as a simplistic import from corporate reporting. Rather, it can serve as a practical framework for examining whether internationalization is environmentally responsible, socially inclusive, and institutionally well governed. Used in this way, ESG is less a branding exercise than a way of asking whether international engagement supports the wider public mission of the university and whether it does so responsibly, ensuring accountability and ethical practice in a globalized world.

The environmental dimension is no longer marginal. Traditional internationalization often normalized travel-intensive models in which physical mobility was treated as an unquestioned indicator of success. Today, universities operate in a context where climate responsibility has become unavoidable. Erasmus+ (2026) explicitly identifies environment and the fight against climate change as a programme priority and encourages forms of learning and cooperation that support greener futures. This does not require abandoning mobility. It requires a more reflective approach to mobility design: asking what purposes mobility serves, when it creates real value, how it can be combined with digital or blended formats, and how institutions can balance educational gains with environmental costs. Sustainable internationalization is therefore not anti-mobility; it is mobility governed more deliberately, integrating ecological considerations into every stage of planning and implementation, from travel choices to digital infrastructure.

The social dimension concerns inclusion, access, and fairness. Here the policy environment is again instructive. Erasmus+ (2026) foregrounds inclusion and diversity, while the Council of the European Union (2024) mobility recommendation explicitly links expansion with the participation of those who have traditionally faced barriers. These priorities are highly significant because they challenge a model in which internationalization often disproportionately served already advantaged students and internationally connected academic groups. A more sustainable approach requires attention to "internationalization for all," including curriculum internationalization, internationalization at home, accessible support structures, and more intentional outreach to those who may not otherwise participate. The social legitimacy of internationalization increasingly depends on whether it broadens opportunity rather than reproducing inequality, fostering equitable access and participation for all members of the academic community regardless of their socio-economic background.

The governance dimension ties these issues together. Universities must decide which partners they work with, what forms of cooperation they prioritize, how they allocate scarce resources, how they balance prestige with reciprocity, and how they respond to ethical, reputational, and geopolitical risks. Governance in this sense is not merely procedural. It is about judgment. It concerns whether institutional structures are capable of linking international ambition to academic mission, whether data and decision-making processes are transparent, and whether internationalization is treated as part of long-term institutional development rather than a collection of disconnected initiatives. OECD's (2025) focus on institutional capacity is therefore especially important, because it suggests that governance quality is not an optional extra; it is a condition for sustainable internationalization, ensuring robust decision-making, ethical oversight, and strategic coherence.

Looked at through this lens, internationalization can no longer be evaluated merely by the quantity of mobility or the number of agreements signed. The more meaningful questions are whether cooperation is strategic, whether participation is equitable, whether mobility is purposeful, whether partnerships are reciprocal, and whether international engagement contributes to institutional resilience, public responsibility, and academic quality. ESG is useful precisely because it helps make these questions visible, providing a comprehensive framework for assessing the true

impact and value of internationalization efforts in a society demanding greater accountability.

5 AI and Digital Transformation in Internationalization Governance

Digitalization has already reshaped internationalization in practical ways, but the spread of generative artificial intelligence adds a new layer of strategic complexity. International engagement increasingly depends on digital infrastructures for recruitment, multilingual communication, student support, virtual collaboration, translation, administration, and data analysis. AI tools can improve responsiveness, lower linguistic barriers, streamline repetitive tasks, and help institutions manage growing expectations with limited staff resources. In principle, this makes internationalization not only more efficient but also potentially more accessible, opening new avenues for global connectivity and service delivery.

Yet the governance implications are substantial. UNESCO's (2023) guidance stresses the need for a human-centred vision, regulatory planning, and human capacity development in relation to generative AI. That warning is especially relevant in international higher education, where communication is often cross-linguistic, cross-cultural, and institutionally sensitive. Internationalization is not only about transaction; it is about interpretation, trust, and relationship-building. When AI enters these processes, universities must ask not only about efficiency but also about the ethical implications, potential biases, and the preservation of human agency and intercultural understanding. This also changes what counts as institutional capacity. It is no longer enough to have internationally active staff and a functioning mobility infrastructure. Universities increasingly need digital literacy, data governance competence, procurement awareness, and the ability to evaluate how new technologies reshape the quality and ethics of international services. In other words, digital transformation reinforces the argument that internationalization is fundamentally a governance issue, requiring proactive policy development, robust data protection, and continuous ethical oversight to prevent the "dehumanization" of international engagement.

6 **Repositioning the International Office as a Strategic Actor**

Once internationalization is understood as a field shaped by sustainability, alliances, project cooperation, inclusion, and digital transformation, the role of the international office must also be reconsidered. Traditionally, international offices were often perceived primarily as service units responsible for mobility administration, agreements, visits, and operational communication. Those functions remain essential. But they no longer capture the full institutional significance of the office, which is evolving to meet the demands of a more complex and strategically sensitive international landscape.

In many universities, the international office increasingly operates at the intersection of strategy, administration, policy translation, and institutional coordination. It connects leadership, academic departments, students, external partners, and funding schemes. It helps interpret policy agendas, identify viable cooperation formats, support project development, coordinate implementation, and ensure that international engagement does not become fragmented across institutional silos. In this sense, the international office becomes not just a provider of services, but a broker of coherence and a translator between different institutional logics. That role is strategic precisely because internationalization today is not self-organizing; it must be curated, aligned, and continuously evaluated to ensure its effectiveness and sustainability.

This repositioning also has an important symbolic dimension. If international offices are viewed only as administrative units, universities risk underestimating the governance work required to turn international activity into institutional value. Someone must distinguish between symbolic and substantive partnerships, between opportunistic expansion and sustainable engagement, between short-term visibility and long-term capacity building.

International offices are often well placed to make these distinctions because they sit close enough to operations to understand what is feasible, but also close enough to strategy to see how internationalization can serve broader institutional goals, thereby acting as critical strategic enablers and "gatekeepers" of institutional quality in the global arena. Without institutional steering, international activity can easily become dispersed, reactive, or symbolic. Universities may accumulate agreements

without meaningful cooperation, increase mobility without widening access, join projects without building long-term capacity, or adopt digital tools without sufficient attention to ethics, quality, and human oversight. The international office is therefore increasingly involved in transforming international activity into institutional value. It helps distinguish between symbolic and substantive partnerships, between opportunistic expansion and sustainable engagement, and between short-term visibility and long-term capacity building.

A deeper governance approach to internationalization can therefore be organized around four interrelated pillars below, (Chytilová, 2026). These pillars should not be understood as a checklist of desirable values, but as a decision-making framework that helps universities evaluate whether internationalization is strategically meaningful, socially legitimate, environmentally responsible, and institutionally sustainable.

First, strategic alignment concerns the relationship between international engagement and the university's academic mission, institutional profile, and long-term development priorities. The central issue is not whether a university is internationally active, but whether its international activities strengthen what the institution wants to become. This pillar therefore requires universities to ask which partnerships, projects, mobility schemes, and alliances genuinely support their educational, research, and societal objectives. Strategic alignment also implies selectivity. Not every international opportunity creates institutional value, and not every partnership should be pursued simply because it increases visibility. A governance-based approach requires the capacity to prioritize, to discontinue low-value activities, and to concentrate institutional energy on forms of cooperation that generate cumulative benefits over time. In this sense, strategic alignment protects internationalization from becoming a collection of disconnected initiatives and turns it into a mechanism of institutional development.

Second, inclusive and responsible engagement addresses the social legitimacy of internationalization. Internationalization has often been associated with opportunity, openness, and mobility, but in practice these opportunities may be unevenly distributed. Students and staff with stronger financial, linguistic, social, or professional resources are often better positioned to benefit from international engagement. A sustainable model must therefore move beyond the assumption that

internationalization is automatically inclusive. It must examine who participates, who remains excluded, and what institutional barriers shape access. This pillar includes mobility support, internationalization at home, curriculum internationalization, transparent selection procedures, targeted communication, and support for participants with fewer opportunities. It also includes reciprocity in partnerships. Responsible internationalization cannot be based only on institutional prestige or one-sided extraction of benefits; it should create meaningful value for all partners involved. The governance question is therefore not simply how to expand participation, but how to ensure that internationalization does not reproduce existing inequalities under the language of global opportunity.

Third, sustainable mobility and cooperation design concerns the quality, purpose, and long-term value of international activities. Mobility remains a central element of internationalization, but it should no longer be treated as an unquestioned good measured mainly by volume. The relevant question is what kind of mobility produces meaningful educational, academic, or institutional outcomes. A short-term visit may be valuable if it leads to curriculum innovation, research cooperation, student engagement, or future project development; conversely, a formally successful mobility may have limited value if it remains isolated and unconnected to broader institutional goals. This pillar also requires attention to environmental responsibility. The issue is not to replace physical mobility with digital formats, but to design mobility more intelligently: combining physical, blended, and virtual formats according to purpose, expected impact, accessibility, and ecological cost.

The same logic applies to project and alliance cooperation. A sustainable internationalization strategy should not aim to participate in as many projects as possible, but to develop a selective and cumulative project portfolio. Project cooperation should be evaluated according to what it brings to the institution across several dimensions: research capacity, educational innovation, curriculum development, staff development, student opportunities, international visibility, knowledge transfer, links with practice, and future funding potential. In this sense, the value of a project cannot be reduced to whether funding was obtained or whether formal outputs were delivered. Its deeper institutional relevance depends on whether it creates spillovers into teaching, research, partnerships, reputation, and organizational learning. Selective project cooperation also requires universities to distinguish between projects that merely consume administrative capacity and

projects that build institutional capacity. Especially in smaller or more specialized institutions, project participation can become fragmented if it is driven mainly by short-term availability of calls, personal contacts, or opportunistic consortium invitations. A governance-based approach therefore requires asking whether a project fits the institution's strategic profile, whether there is sufficient internal ownership, whether the expected outputs can be used beyond the project lifetime, and whether the cooperation strengthens areas in which the institution wants to develop. Sustainable cooperation requires continuity, implementation capacity, internal ownership, and mechanisms for transferring benefits back into the institution. It is therefore not enough to join networks or projects; universities must be able to absorb, use, and institutionalize what such cooperation produces.

Fourth, AI-enabled but human-centred governance responds to the growing role of digitalization and artificial intelligence in international higher education. AI can support internationalization by improving communication, translation, student services, data analysis, document processing, and administrative efficiency. It can help international offices manage growing expectations under conditions of limited staff capacity. However, AI also introduces new governance risks. Internationalization involves culturally sensitive communication, trust-building, interpretation of individual circumstances, and decisions that may affect access to opportunities. These processes cannot be reduced to automation without careful human oversight. A human-centred approach requires transparency about where AI is used, protection of personal data, awareness of bias, and clear responsibility for decisions. AI should therefore be understood as an enabling infrastructure, not as a substitute for institutional judgment. Its value lies not in replacing the relational dimension of internationalization, but in freeing human capacity for tasks that require interpretation, empathy, negotiation, and strategic reasoning.

These four pillars are mutually reinforcing. Strategic alignment without inclusion may produce prestigious but socially narrow internationalization. Inclusion without strategic alignment may broaden access but remain institutionally fragmented. Sustainable mobility without digital capacity may become administratively inefficient, while digital transformation without human-centred governance may undermine trust and quality. The strength of the framework therefore lies in the interaction among the pillars. It shifts the evaluation of internationalization from isolated indicators toward the quality of institutional steering.

Under such a model, the international office is repositioned from a primarily administrative support structure to a strategic actor contributing to sustainable institutional development. This includes supporting strategic partner selection, improving the quality of implementation, strengthening inclusion and transparency, identifying synergies between mobility, projects and research cooperation, and ensuring that internationalization contributes to long-term institutional resilience.

7 Reflections from Practice

At Skoda Auto Vysoka skola, this perspective is closely linked to the ongoing shaping of Strategy 2035. In that context, addressing internationalization through a governance lens is not optional but increasingly necessary. The aim is not only to increase international activity, but to improve how internationalization functions: how mobility is organized, how outcomes are assessed, how services are delivered, how equal access and transparency are ensured, and how international engagement contributes to wider institutional quality. From this point of view, governance begins not in abstraction but in the continuous improvement of concrete processes that shape the everyday experience of students and staff (Chytilová, 2026).

This perspective is closely connected to the ongoing shaping of Strategy 2035. For a smaller and professionally oriented institution, internationalization cannot be based on unlimited expansion. The principle of quality over quantity is therefore essential. Partnerships are increasingly meaningful when they support more than one institutional objective: student opportunities, curriculum development, research cooperation, staff development, project capacity, links with practice, knowledge transfer, and reputation. A partnership that exists only formally has limited value. By contrast, a smaller number of well-developed partnerships can generate repeated mobility flows, teaching cooperation, research contacts, joint project ideas, and stronger institutional visibility. In this sense, internationalization becomes a matter of strategic portfolio development rather than simple partner accumulation.

One important step has been to treat mobility itself as an area of quality enhancement rather than mere administration. This includes a stronger focus on the effectiveness of student and staff mobility, with explicit attention to equality, inclusion, transparency, and service quality. Such principles should be self-evident, but in practice they require systems, routines, and institutional attention. Practical

measures have therefore included the strengthening of advisory and support formats.

Student mobility at Skoda Auto Vysoka skola is not treated only as an administrative output, but as a supported experience that must be monitored before, during, and after the stay. Formal feedback through university system is useful, but it is not sufficient on its own. For outgoing students, ongoing consultations during the mobility make it possible to understand how the stay is developing, whether the student feels academically and practically supported, and whether any difficulty should be addressed while there is still time to intervene. For Erasmus incoming students, a similar logic applies through consultations during the semester, informal meetings, shared dinners, and community-building activities. These concrete formats matter because they turn mobility from a one-off transaction into a relationship-based process of support, feedback, and institutional learning. Activities such as Erasmus Days, dialogue-oriented events, and more visible communication about mobility opportunities also play an important governance role. They are not merely promotional events. They lower information barriers, make internationalization more visible inside the institution, and help students and staff understand mobility as a realistic and supported opportunity rather than as an abstract programme. In this way, inclusion is created not only through formal eligibility rules, but through repeated communication, trust-building, peer examples, and spaces where participants can ask questions and share experience. This is particularly important where participation may be limited by uncertainty, lack of confidence, insufficient information, or the perception that international mobility is only for a narrow group of already motivated students and staff. Even seemingly modest innovations matter because they improve not only service provision but also participation quality and institutional responsiveness (Chytilová, 2026).

Staff mobility requires a different but equally deliberate approach. Here the issue is not only whether staff are formally eligible to participate, but whether they are motivated, prepared, and able to connect mobility with their academic or professional development. Ex ante support, for example through informal formats such as “coffee with the Vice-Rector”, can help academic and administrative staff discuss possible mobility plans, clarify expectations, identify suitable partners, and overcome uncertainty. This type of support is important because staff mobility often

depends not only on administrative information, but also on confidence, time constraints, workload, and the perceived usefulness of the experience.

The value of staff mobility should also be judged by what happens after the visit ends. A teaching or training mobility has greater institutional relevance when it produces a follow-up: renewed partner communication, joint teaching ideas, comparison of curricula, research contacts, project discussions, or internal sharing of good practice. Ex post services and visibility are therefore important. Mobility stories, short profiles, website news, internal communication, and staff medallions can make individual experience visible to the wider academic community and motivate others to participate. In this sense, staff mobility becomes not only an individual professional activity, but also a tool for internationalization culture-building, peer inspiration, and institutional learning.

The same selective logic applies to project cooperation. International projects should not be pursued only because a call is available or because the university is invited into a consortium. Their value depends on whether they fit the institution's profile and whether their outcomes can be used beyond formal reporting. A well-selected project can simultaneously strengthen research capacity, curricula, staff expertise, student opportunities, applied cooperation, international visibility, and future funding potential. By contrast, a poorly aligned project may consume administrative and academic capacity without creating lasting value.

Based on personal experience, a particularly important element is the multiplication effect of project cooperation. Once the institution develops competence in a specific project area, it should not treat the project as an isolated episode, but as a platform for further development. A successful project can create methodological know-how, administrative routines, partner trust, better future applications, and stronger academic specialization. The aim is therefore to build on areas where the university is already developing strength, deepen expertise over time, and use one project as a stepping stone toward more ambitious cooperation. This cumulative logic is especially important for smaller institutions because it allows them to concentrate limited resources and gradually become more competitive in selected international project ecosystems.

Alliance-oriented cooperation can support this cumulative approach. Skoda Auto Vysoka skola's relationship with the Ulysseus European University Alliance as an associate partner illustrates a move from isolated bilateral contacts toward a more structured collaborative environment (Skoda Auto Vysoka skola, 2025). The value of such cooperation does not lie only in symbolic affiliation or external visibility. It lies in access to economies of scale: shared know-how, joint project preparation, thematic working groups, distributed expertise, mutual learning, and cooperation formats that would be difficult for one institution to generate alone. For a smaller university, alliance cooperation can therefore help connect mobility, projects, innovation, knowledge transfer, and institutional learning in a more systematic way.

Digitalization of international office processes follows the same governance logic. Its value is not primarily technological, but organizational and analytical. Better digital processes can make mobility pathways more transparent, identify bottlenecks, improve monitoring, reduce dependence on informal memory, and support more consistent service quality. At the same time, digitalization has practical limits. Some Erasmus+ and related European administrative processes may still require specific documents, signatures, or paper-based evidence. A realistic digitalization strategy therefore cannot be based on the illusion of complete digital replacement. It must distinguish between processes that can be simplified internally and those that remain constrained by external compliance requirements. The same caution applies to AI-supported tools. They can help with communication, translation, documentation, and routine administration, but they cannot replace human judgment. Internationalization involves trust, cultural interpretation, negotiation, individual circumstances, and sensitive communication with partners, students, and staff. Digital and AI tools are most valuable when they release human capacity from repetitive work and redirect it toward higher-value tasks: advising students, supporting staff, developing partnerships, identifying project opportunities, and connecting international activities with institutional priorities.

Taken together, these experiences show that the four pillars of sustainable internationalization governance are not abstract categories, but practical leadership questions. Strategic alignment is visible in the move toward quality over quantity in partnerships. Inclusive and responsible engagement is visible in consultations, Erasmus Days, shared dinners, dialogue-oriented formats, and more accessible support for outgoing and incoming students. Sustainable cooperation design is

visible in the expectation that staff mobility, projects, and alliances should generate follow-up value rather than remain isolated activities. Human-centred digital governance is visible in the effort to digitalize what improves transparency and monitoring, while preserving human judgment where standardization would reduce quality.

A further lesson from practice is that sustainable internationalization depends on academic ownership across departments, rather than on coordination by the international office alone. At Skoda Auto Vysoka skola, this has involved mapping existing internationalization activities at the departmental level by International Office, including current international contacts, teaching-related cooperation, research links, mobility experience, and areas with further cooperation potential. The purpose of this activity is not merely descriptive. It creates a more nuanced understanding of the institution's internal internationalization capacity and makes it possible to connect external opportunities more precisely with academic expertise. This is particularly important when engaging with foreign partners, incoming delegations, visiting academics, or potential project consortia. In this role, the international office acts less as a separate administrative unit and more as a strategic intermediary, helping to translate dispersed departmental experience into more coherent and development-oriented international cooperation. Without such academic ownership, internationalization may remain administratively functional but academically thin; with it, it becomes embedded in the intellectual and strategic life of the institution.

Finally, practice also highlights the growing importance of risk awareness and institutional resilience. Contemporary internationalization takes place in an environment shaped by geopolitical uncertainty, changing programme rules, reputational sensitivities, digital risks, uneven partner capacities, and dependence on a limited number of key staff members. Sustainable internationalization therefore also requires the ability to anticipate vulnerabilities: which partnerships are strategically promising but administratively demanding, which projects create long-term dependence, which mobility flows may be exposed to external shocks, and which processes rely too heavily on informal knowledge or individual experience. From this perspective, governance is not only about expanding opportunities, but also about making internationalization more resilient, transparent, and institutionally embedded.

The contribution of the Skoda Auto Vysoka skola experience is not a universal model, but a practice-based demonstration of how internationalization can be governed more selectively, concretely, and deliberately in line with institutional strategy.

7 Conclusion

Internationalization in higher education has entered a phase in which activity growth alone no longer captures institutional reality. This necessitates a paradigm shift from a purely activity-based understanding to a governance-centric approach that prioritizes institutional steering over expansion.

The contribution of this paper was to conceptualize internationalization as a component of sustainable university governance. It argues for a shift from activity to alignment, from expansion to steering, and from symbolic visibility to responsible and value-based engagement. The proposed four-pillar framework highlights that sustainable internationalization depends on strategic alignment, inclusive and responsible engagement, sustainable mobility and cooperation design, and AI-enabled but human-centred governance. These dimensions are mutually reinforcing: internationalization becomes institutionally meaningful only when opportunities are selected strategically, implemented inclusively, connected to academic and project development, and supported by governance mechanisms that preserve human judgment, transparency, and trust.

The practice-based reflection from Skoda Auto Vysoka skola further suggests that sustainable internationalization is not created by formal strategies alone, but through concrete managerial decisions and institutional routines. These include the principle of quality over quantity in partnerships, stronger feedback and support mechanisms in student mobility, ex ante and ex post support for staff mobility, selective and cumulative project cooperation, the multiplication effect of building on existing strengths, the use of alliances to generate economies of scale, and realistic digitalization that respects both institutional needs and external compliance requirements. The practical value of governance therefore lies in the ability to transform individual activities into institutional capacity.

As a conceptual and reflective article, the paper does not provide empirical validation of the proposed framework. Its value lies instead in clarifying an analytical perspective and translating it into practical governance questions that can guide institutional strategy.

Future research could build on this conceptual framework by applying it to selected institutional cases or by using expert interviews to assess its practical relevance. Rather than relying on extensive cross-institutional datasets, future studies may explore how international offices perceive their strategic role, organizational constraints, and the potential use of AI-supported tools in managing internationalization.

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Summary

This study examines internationalization in higher education at a moment when its traditional language of mobility, agreements, and external visibility is becoming insufficient. Against the background of European policy integration, sustainability pressures, geopolitical uncertainty, and the rise of generative artificial intelligence, internationalization is presented not as a separate institutional agenda, but as a test of how universities govern complexity. The paper develops a four-pillar framework of sustainable internationalization governance, built around strategic alignment, inclusive and responsible engagement, sustainable mobility and cooperation design, and AI-enabled but human-centred governance. These pillars are not treated as abstract principles, but as a governance architecture through which universities can evaluate whether international engagement creates academic value, social legitimacy, institutional capacity, and long-term resilience. Particular attention is paid to the changing role of international offices, which increasingly act as organizational interfaces where policy priorities, academic ambitions, operational constraints, and partnership opportunities are translated into practice. The reflection on Skoda Auto Vysoka skola and Strategy 2035 illustrates how this framework can inform concrete institutional choices: building quality rather than quantity in partnerships, supporting mobility as a lived experience, using projects cumulatively rather than episodically, strengthening departmental ownership, digitalizing realistically, and anticipating risks. The study concludes that sustainable internationalization is ultimately less about how far a university reaches outward than about how intelligently it converts international exposure into academic depth, organizational learning, and resilient governance.

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SUSTAINABLE GOVERNANCE IN THE AGE OF ARTIFICIAL INTELLIGENCE: INTERDISCIPLINARY PERSPECTIVES ON ESG, DIGITAL TRANSFORMATION AND CORPORATE RESPONSIBILITY

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This international scientific monograph explores contemporary challenges and opportunities in governance, sustainability, and digital transformation in an era of rapid technological advancement. Bringing together contributions from researchers across different countries and disciplines, the volume examines how artificial intelligence, ESG frameworks, corporate responsibility, innovation, regulatory developments, and digital technologies are reshaping organizations, institutions, and society. Particular attention is given to sustainable governance, responsible decision-making, organizational adaptation, and the creation of long-term value in increasingly complex environments. The chapters combine theoretical insights, empirical research, and case studies, offering interdisciplinary perspectives on the evolving relationship between technology, sustainability, and governance. By bridging academic knowledge and practical implications, the monograph contributes to current debates on sustainable development, responsible innovation, and governance transformation. It is intended for researchers, academics, students, policymakers, and practitioners interested in the future of governance, sustainability, and digital change.

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