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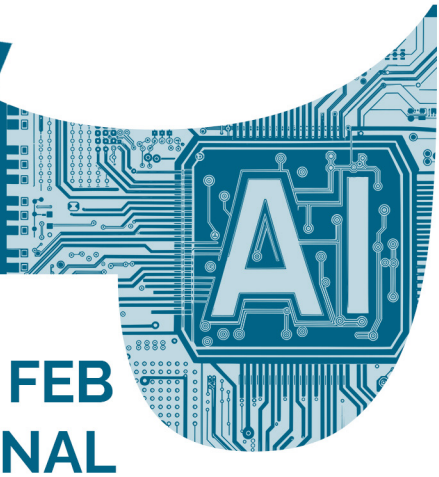

9TH FEB INTERNATIONAL SCIENTIFIC CONFERENCE

Sustainable Management in the Age of ESG and AI: Navigating Challenges and Opportunities

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Jernej Belak
Zlatko Nedelko

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KEYNOTE SPEECHES

Sustainable Management in the Age of ESG and AI: The Role of Business Schools

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The purpose of this presentation is to compare and learn about the concept of sustainable management by exploring the journeys of three business schools in three different countries. A multiple-case study approach is employed to realise this purpose. Specifically, three business schools, namely, Wellington School of Business and Government at Victoria University of Wellington, New Zealand; the College of Business, Hospitality and Tourism at Fiji National University, Fiji; and the Rajagiri Business School, Kochi, India are analysed in the age of ESG and AI. The findings once again highlight that sustainability is a holistic concept, and both content and context are integral aspects in a journey towards sustainable management.

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COPING WITH GLOBAL WARMING: SYSTEMIC DESIGN, SCOPE AND SCALE

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The issue we are addressing is the environmental complexity facing today's society. A systemic framework is presented that enables decision-makers to respond effectively to climate change. The question is: "How can society find a holistic approach to mastering the complexity of global warming it is confronted with?" Dominant approaches to coping with climate change are almost exclusively one-dimensional. The focus is on combating greenhouse gases. In contrast, we advance a more holistic, multi-layered approach. Our study focuses on the dimensions of scope and scale, with their sub-dimensions. The framework we propose introduces a systemic perspective that charts sustainable paths into the future. The novel focus is on leveraging the complementarity of strategies of mitigation, adaptation and structures of recursion. This way, society's repertoire for weathering climate change will be enhanced in multiple ways.

PROCEEDINGS

Sustainable Management and Business in the Area of Grocery Shopping - The Efficiency of Grocery Shopping (EOGS) Project

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Net sales in the German food retail sector exceeded EUR 250 billion in 2022. This market is therefore not only interesting due to its sheer size, but also due to recent developments in online retail. In addition to the dominance of traditional store sales, online delivery services and providers that deliver groceries to your doorstep in just a few minutes are alternatives for customers. Various perspectives need to be examined to assess the sustainability of business and trade in this sector. On the one hand, it is about providers with a focus on delivery services, who are competing for customers' favour with various concepts and delivery modalities. On the other hand, the focus is on consumers, who now have a range of alternatives for purchasing food. Additionally, one can investigate how sustainable a delivery service purchase is compared to a stationary purchase. Methodologically, the project is carried out with practical case studies with a recording and analysis tool (EoGS-tool). The first stage of the project will focus on testing the practicability and usability of the tool and evaluating the initial results. In a second stage, the recording and evaluation of purchases is to be expanded through cooperation with other universities.

Keywords:
case studies, economic efficiency, grocery shopping, online food delivery services, sustainable business models

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1 Introduction

According to statista, net sales in the German food retail sector amounted to more than 252 billion Euros in 2022 (statista, 2024a). This market is therefore not only interesting due to its sheer size, but also due to recent developments in online retail. In addition to the dominance of traditional store sales, online delivery services and providers that deliver groceries to your doorstep in just a few minutes via inner-city delivery hubs are alternatives for customers.

Two perspectives need to be examined to assess the sustainability of business and trade in this sector. On the one hand, it is about providers with a focus on delivery services, who are competing for customers' favor with various concepts and delivery modalities. On the other hand, the focus is on consumers, who now have a range of alternatives for purchasing food.

The EoGS-project focuses on three central questions:

Q1. Where do end consumers buy economically? In stationary retail or online retail?
Q2. Do online delivery services work profitably compared to bricks-and-mortar retail?
Q3. How "ecologically sustainable" is online shopping compared to bricks-and-mortar retail?

Methodologically, the project is carried out with practical case studies for which an Excel-based recording and analysis tool is used (EoGS-tool). The first stage of the project in winter semester 2024/25 will focus on testing the practicability and usability of the EoGS-tool and evaluating the initial results. In a second stage, the recording and evaluation of purchases is to be expanded through cooperation with other universities in Germany and abroad.

2 Theoretical Background / Literature review

Food retail is the sector with the highest turnover in the entire German retail sector (statista, 2024b). The product range of food retail companies consists primarily of food, but often also includes near-food products such as cleaning products. Over-the-counter retail is characterized by various forms of operation such as

supermarkets, discounters, hypermarkets and self-service department stores. Before the internet age, this classic form of distribution was the only one that existed, so this phase could be described as "Grocery 1.0".

New forms of distribution emerged with the internet, although these only had a niche existence under the heading of "food eCommerce". One example is the company myTime (myTime, 2024), which has been offering groceries on a website and sending them by parcel since 2012. Another example is REWE, which with a market share of over 20% is one of the top five German food retailers. They operate a delivery service with small trucks since 2012. This phase could be described as "Grocery 2.0", as the internet is used as a sales channel here with a delivery time of a few days (Singh & Singh, 2023).

The coronavirus pandemic was an accelerator for further dynamic development of the online market (Wiedemann et al., 2023). In addition to a growth spurt in sales in the online sector, new forms of distribution, which can be subsumed under the keyword "quick commerce", attracted attention. Customers are supplied from so-called city hubs or micro-depots, which are located in city centers and promise a delivery time of ten to twenty minutes. Examples of these companies are Gorillas, Flink and Picnic. This development phase could be described as "Grocery 3.0", in which traditional forms of distribution compete with established online delivery services and quick commerce service providers.

Table 1: Key characteristics of selected grocery online delivery services

Company	Product range	Forms of distribution/ Grocery x.0	Delivery type	Means of transport used	Delivery time promise
REWE	Full range retailer	Stationary and online/ Grocery 1.0/2.0	Regional hubs	Special conversion truck (ICE)	Next days with time slots
myTime	Full range retailer	Online/ Grocery 2.0	Parcel delivery	CEP vehicles	Next days
Flink	Limited product range	Online/ Grocery 3.0	Micro depot	Bicycle	Same day, > 10 minutes
Flaschenpost	Limited product range	Online/ Grocery 3.0	Micro depot	Van (ICE)	Same day, 120 minutes

Source: author's compilation

As the focus of the analysis is on online food delivery services, the following table provides an excerpt of the current grocery market with relevant providers and their key characteristics. The corresponding weblinks are listed under references.

The differences between the various providers are very clear. The main distinguishing features are the selection of products (Product range), the means of transport used (Means of transport used) and the promised delivery times (Delivery time promise).

3 Methodology

As part of the EoGS-project, working groups are formed with several students who, in a first step, select two companies, one of which is an established stationary provider (Grocery 1.0) and the other an online provider (Grocery 2.0/3.0). In a second step, the working groups carry out various purchases in both companies. The relevant data is recorded using the Excel-based EoGS-tool. Various areas (accessible via Excel sheet registers) are available for data collection and analysis, which are briefly outlined below.

Shopping

All purchases are documented at item level in this sheet register. In addition to the product name, price and quantities, additional characteristics are recorded. These include, for example, information on packaging and a classification of logistical requirements. A scale from "very high" (e.g., for eggs) to "very low" (e.g., for tinned food) is available for the latter characteristic.

Price-Comparison

For selected products, one can compare the purchase prices from the various sources of supply in this register. It must be ensured that the products are the same and of the same quality. Differing packaging sizes are compensated by standardization. This allows to test the obvious hypothesis that products from online sources tend to have higher prices than stationary products. In addition, care must be taken to only compare so-called retail benchmark prices and not offer prices.

Opportunity

The name of this sheet register already underlines the focus of the content: opportunity costs. This central term in economics describes the lost profit or benefit of an alternative. Opportunity costs typically arise when capital is used for investments, in which the lost interest on a safe investment reduces the return on the investment as imputed interest. In the case of grocery shopping, opportunity costs arise for stationary shopping from the time spent on various stationary shopping activities, such as driving to the store or waiting in a checkout queue. For online shopping costs arise from dealing with apps or web sites and the delivery time of groceries ordered online. These costs are interesting from the perspective that online food orders are advertised as "time-saving" (ntv, 2012). Based on Coase's transaction cost theory, these additional costs to the purchase costs can also be described as typical "transaction costs", which consist of initiation and processing costs (Coase, 1937; Williamson, 1975; Picot & Dietl, 1990). The time required for shopping is based on a process-related sequence that comprises various process stages and is supplemented by "real" costs in the form of transportation costs depending on the means of transport used for shopping in a stationary store. In addition, the environmentally relevant CO_2 emissions are determined from the customer's perspective (Klein & Popp, 2023).

Table 2: Process structure of the purchasing processes from customer's perspective

Process step description	Examples of retail outlet	Examples of online delivery
01-Prepare shopping	Look for bags, pack up empties	Start up PC, open app
02-Reaching the shopping destination	Find vehicle, drive to store, park, walk to store	Open the website, log in
03-Vehicle costs outward and return journey	E.g. car (ICE, BEV), bicycle, public transport	/
04-Shopping	Take goods from the shelves	Search and add to shopping cart
05-Checkout	Checkout line, pay	Pay for order
06-Drive to home	Pick-up vehicle, pack, drive to home, park, walk to home	/
07-Online delivery time	/	Delivery time
08-Unpacking/clearing out	Unpacking things, putting things away, disposing of garbage	Unpacking things, putting things away, disposing of garbage

Source: author's compilation

By adding up the individual time expenditures, you can compare which form of purchasing is actually more time-saving. The average purchasing times per purchase and per purchasing item are calculated as key figures. Opportunity costs are calculated by multiplying the total time spent by an hourly rate in Euros per hour. From a student perspective, this could be an hourly rate that represents typical pay for student jobs such as the current minimum wage in Germany of 12.82 Euros/hour. In view of the fact that you cannot work without interruption and that buying food is one of the necessities of life, one can also set lower values. It is more difficult to set a cost rate for the delivery time of food ordered online. Argumentatively, this cost rate could be based on the costs incurred due to the delivery time-related loss of the ordered food or the risk of late or non-delivery. In addition to the opportunity costs, thus time costs, the costs for vehicle use incurred for the outward and return journey to the stationary shopping location are also recorded. Average values for consumption and costs as well as values (coefficients) for tank-to-wheel (TtW) and well-to-wheel (WtW) CO_2 emissions are provided for the means of transportation used.

Delivery variable Costs

While the opportunity section addresses the perspective of a customer, the next two sections deal with the perspective of an online delivery service; starting with variable costs. When delivering food, the respective company has to manage various process steps itself, which are usually taken over by the customer in the case of a stationary purchase. In addition to costs, energy consumption and CO_2 emissions are allocated using average values for the vehicles used. The following table shows the process steps for which costs can be allocated in each case.

Table 3: Process structure of online delivery service

Process step description	Costs description
01-Picking	Cost of order picking
02-Transport packaging	Cost of packaging the ordered goods depending on the logistical requirements, e.g. pressure or temperature sensitivity
03-Shipment	Depending on the business model, different modes of transportation can be recorded, e.g. vehicles or parcel shipping
04-POS packaging	In some business models, packaging is only carried out directly before delivery at the POS (point of sale)

Source: author's compilation

Delivery Fixed Costs

Fixed costs are also referred to as operating costs and are independent of quantity. In this respect, this section includes, for example, rents, leases, IT costs, insurance, etc., which are necessary to operate the business model for online delivery. Determining exact cost values is a particular challenge, especially when determining or estimating fixed costs such as rent or insurance. In this respect, the basic principle of making conservative estimates applies. For this reason, in addition to the possibility of applying various reference values for the allocation of fixed costs to a delivery (e.g., number of parcels delivered, number of food items delivered or the number of orders (commissions)), one has the option of setting the fixed cost component to zero to exclude this aspect from evaluation and analysis.

Profit

This section deals with the profitability comparison of the various business models. In a first step, the return for stationary as well as online purchases is calculated on the basis of average values for trading margin and costs from an empiric study (Dellbrügge, 2022). In a second step, a profit calculation is created for online delivery. This takes into account additional sales that are usually charged in online trading, such as delivery charges or fresh produce surcharges. For the purchase cost of goods sold, one can either use the same values for stationary retail or use modified values if you assume that the purchasing conditions are either better or worse than in stationary retail. Credit notes are also included, taking into account sales, cost of goods sold, variable delivery costs and any fixed cost components. Credit notes play virtually no role in stationary retail, as shoppers generally select the goods themselves, particularly in the case of fruit and vegetables. For online delivery services, the risks of damage or deterioration in quality during transportation are much higher. This applies in particular to foods that have high logistical requirements because of pressure or temperature sensitivity. As it usually makes no sense to return damaged goods, a credit note is usually issued. Profits are calculated at different levels. The calculation of Profit I is shown here as an example:

Table 4: Profit I calculation schema

Calculation scheme	Explanation	Example
Net turnover	Cash value without VAT	50.00 Euro
x Delivery Margin in %	Based on empiric study	30.00 %
= Delivery Margin absolute		15.00 Euro
+ additional revenue	E.g. delivery charges or freshness surcharges	5.00 Euro
= Delivery shopping margin (calculated)		20.00 Euro
./. Delivery costs I	Calculated in section Delivery variable costs; only direct energy costs of vehicles	27.32 Euro
= Profit I		-7.32 Euro

Source: author's compilation

4 Results

In order not to go beyond the scope of this paper, the following is limited to selected results from cases of the course Logistic Management, 5th semester of Bachelor Logistikcs, in winter term 2024/25. The results shown provide answers to the questions formulated at the beginning. The following results relate to practical case studies with the companies EDEKA, REWE, myTime and Flink.

Table 5: Excerpts from the results (∑ = sum; Ø = average; n.c. = not calculated)

Company	Grocery x.0	No. of purchases/ total no. of purchased items	Cash sum incl. VAT/ net sum excl. VAT in €	Opportunity duration per purchase/ per item in min	Profit* (in Euro) /return on net sales (%)	TtW per purchase/ per item in kg CO_2
EDEKA	1.0	4/62	147.52/132.83	50.50/3.3	€4.7/3.6%	2.01/0.13
REWE	1.0	2/15	25.66/23.36	32.4/4.3	€0.6/2.4%	0.15/0.02
		∑ 6/77	∑ 173.18/156.19	∑Ø **41.45**/3.8	∑Ø **2.7** (3.0%)	∑n.c.
REWE	2.0	1/19	58.41/52.07	33.0/1.7	**€-7.4** (-14.2%)	9.65/0.51
myTime	2.0	2/15	34.81/31.77	15.1/2.0	**€9.0** (28.4%)	0.55/0.07
		∑ 3/34	∑ 93.22/83.84	∑Ø **24.05**/1.85	∑n.c.	∑n.c.
Flink	3.0	2/15	30.25/27.58	Ø **4.20**/0.60	**€7.4** (26.7%)	0/0

Source: author's compilation * Profit (for retail outlet) and Profit I (for online 2.0/3.0)

5 Discussion

With regard to the first question (Q1), economic efficiency from the customer's perspective, we will only briefly discuss shopping time (opportunity time) here without consideration of the delivery time. If you compare the time it takes to shop, online shopping actually saves a considerable amount of time. The average shopping time per purchase in bricks-and-mortar stores is 41.45 minutes compared to just 24.05 minutes for online retailers type Grocery 2.0. Ordering via the (Flink) app seems to be even more effective, as it only takes a very short 4.2 minutes per purchase. If you look at the profit situation (Q2), you can see that in principle, profits can be made in stationary retail, albeit at a low level; in this case 2.7 Euros, which corresponds to an industry-standard return on sales of 3.0%. In the case of REWE online delivery, the use of a delivery vehicle combined with a long delivery time resulted in high delivery costs, which ultimately led to a loss (€-7.4). The parcel shipper MyTime benefits from high extra fees that are charged for shipping. The calculated profit is €9.0. The profit of €7.4 with Flink comes from the low delivery costs due to the short delivery distance, which is covered by bicycle. However, it should be noted once again that certain types of costs are not included in profit I, in particular fixed cost components, credit notes and full cost components for the use of vehicles. Against this background, it can be assumed that the calculated profit margins can vary considerably in practice. When it comes to sustainability (Q3), the route and the vehicle used play the biggest role. If you go to the supermarket on foot or by bike, the CO_2 emissions are of course significantly lower than if you use a car. The same applies to online delivery services. Flink scores very well here, as bicycles are used. For myTime, an average value of CO_2 emissions per parcel was used for parcel delivery mode.

6 Conclusions

At this point, it must be emphasized that no general conclusions can be drawn due to the limitations of the collected data. Firstly, only a few purchases were made and secondly, the items purchased represent only a fraction of the total range of goods in the food retail sector. Thirdly, the analysis is limited to the last mile of distribution and does not take the entire supply chain into account. Nevertheless, insights can be gained from the results. Given the background objective of engaging students with interesting tasks that include both theoretical and practical aspects, the EoGS-

project can be considered a success. The participating students learned how to deal with scientific methodology, basic rules in the construction of databases and their evaluation. The EoGS-tool used was revised and improved several times. In addition, numerous discussions made it possible to deal with business management issues against the background of practical experience, e.g., the consideration of opportunity and transaction costs in purchasing decisions or when choosing between a brick-and-mortar store or online alternatives. In the second step already mentioned in the introduction, even more case studies now need to be carried out in order to increase the significance of the results. Collaboration with other universities in Germany and abroad is planned.

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THE ROLE OF SPORT INNOVATION IN GLOBAL ECONOMICS -THE HUNGARIAN CASE

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This paper examines the critical relationship between sports innovation and global economics, focusing specifically on the Hungarian context. As the sports industry continues to emerge as one of the fastest-growing sectors worldwide, it not only serves as a source of entertainment but also plays a significant role in economic activity, job creation, and community development. The study highlights the strategies employed by Hungarian football clubs to enhance organizational performance through technological advancements, knowledge management, and sustainable practices. By conducting a systematic literature review and analyzing empirical data from in-person interviews with representatives from several Hungarian football clubs, this research elucidates how innovation can drive economic growth by attracting investments, enhancing productivity, and fostering vibrant communities. The literature review emphasizes the importance of managerial knowledge, organizational culture, and external collaborations in achieving innovation success. Furthermore, it underlines the potential of sports innovation as a catalyst for economic growth, particularly through increased sports consumption, infrastructural investments, and community engagement. Ultimately, the findings of this study aim to provide valuable insights for practitioners and policymakers in the sports sector, demonstrating that embracing innovation can enhance competitive advantage and contribute meaningfully to both local and global economic landscapes.

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1 Introduction

The sports industry is among the fastest-growing sectors worldwide, serving as a source of entertainment and a key driver of economic activity, job creation, and community development. This paper investigates the complex relationship between sports innovation and global economics, focusing on Hungary. Known for its rich sporting heritage, especially in football, Hungary offers a valuable case study examining how innovative practices can improve organizational performance and foster economic growth. By analysing the innovation strategies of several Hungarian football clubs, this research highlights the importance of technological advancements, knowledge management, and sustainable initiatives in shaping the future of sports organizations. The literature review covers various aspects of innovation—from organizational culture to external collaborations—that significantly influence performance outcomes. Additionally, the study emphasizes how sports innovation can stimulate economic development through increased investment, enhanced productivity, and stronger community engagement. Combining a systematic review of scholarly literature with empirical data from local clubs, this research aims to provide actionable insights for practitioners and policymakers. Ultimately, it demonstrates that embracing innovation enhances the competitive edge of sports organizations and contributes to broader economic progress within Hungary and beyond.

2 Theoretical Background / Literature review

2.1 Innovation and performance

Research indicates that the most successful welfare states in Europe, particularly those in the Nordic region, are the leading innovators, highlighting the critical interplay between social systems and innovation performance (Hajighasemi et al., 2022). Technological advancements have drastically reshaped the sports sector, driving the need for innovative approaches. Ratten (2020) posits that technology is a fundamental driver of the sports industry's global competitiveness, necessitating the development of comprehensive innovation management strategies. As Morrison (2023) further affirms, record-breaking performances in sports are increasingly reliant on continuous advancements in technology and biomedical innovations. The integration of key stakeholders including sports managers, coaches, and researchers

is essential for examining technological innovations within sports (Ringuet-Riot et al., 2014). Systematic reviews indicate that football adopts GPS technology more extensively than other team sports, showcasing the sector's potential for technological integration (Cummins et al., 2013). As the dynamics of sports innovation emerge, numerous tools and methods influence an organization's ability to sustain innovation performance. Factors such as strategic planning, management engagement, and knowledge sharing are crucial for fostering a culture of innovation (Hasgalla et al., 2018). Sustainability is becoming also a focal point in organizational innovation discourse. Studies by Inthavong et al. (2023) reveal that adopting green innovation practices not only improves environmental outcomes but also enhances overall organizational performance. The complexity of implementing effective innovation strategies, particularly within sports organizations, calls for further exploration of these interactions.

2.2 Relation between sport innovation and global economics

Innovation drives economic growth by enhancing productivity and enabling organizations to produce more with the same resources. The sports sector, a multi-billion-dollar industry, closely ties to economic principles, influencing key financial decisions like ticket pricing, player salaries, and sponsorships. Understanding these economic factors helps sports organizations optimize revenue and operational efficiency, essential for sustainability and growth. Innovation also plays a vital role in globalization, aided by technological advancements that lower trade barriers and foster international collaboration. This enhances the global competitiveness of the sports industry. Sports innovation focuses on developing processes and products that improve the sports experience, attracting customers, and increasing efficiency. Football significantly contributes to economic development through job creation, tourism, and local business growth by boosting ticket sales and broadcasting revenues. As a prominent sector, football drives economic and social growth through collaboration between sports investors and government entities. When effectively leveraged, sports can enhance tourism and foster community connections. Investment in infrastructure, supported by public-private partnerships, is crucial for sports initiatives and community resources. Sports organizations promote civic pride and community cohesion while creating job opportunities, from administrative roles to event staff. They often engage with local communities to provide education and training programs, further impacting local economies

(Deloitte, 2024). Football is a significant economic driver that fosters financial growth and job creation worldwide. Major tournaments like the FIFA World Cup and UEFA European Championship greatly impact host cities by attracting tourists and stimulating local businesses. The infrastructure developments tied to these events create construction jobs and improve transportation and community facilities after the tournaments end. At the club level, football clubs are central to the industry, utilizing various strategies to generate revenue. Professional leagues and international cups secure lucrative television deals, enhancing clubs' financial stability. Match-day revenues from ticket sales, concessions, and merchandise also contribute substantially to the local economy. Additionally, careers in football, such as players, coaches, or managers, are financially rewarding, reflecting the sport's strength and popularity. According to Aygün et al. (2023), note a reciprocal relationship between economic growth and the sports industry, with increased sports consumption contributing to economic expansion. Football clubs are crucial in this dynamic, generating significant revenue from ticket sales, sponsorships, and broadcasting rights, while also supporting urban development and attracting investments. Sports events drive economic development and sustainability, as a thriving economy positively affects the sports sector. This interplay has led countries to focus on football as a key investment for enhancing domestic markets and international connections. Significant events like the FIFA World Cup and Olympic Games require substantial financial commitments for infrastructure, while smaller events often rely on national support. Investments in sports infrastructure are essential for urban development and addressing underdevelopment in sports. Professional football clubs aim for excellence in both business performance and on-field success, making economic growth a vital consideration.

3 Methods

This paper utilizes a three-step methodology to explore the relationship between sports innovation and economic growth. First, it reviews tools and methods influencing the innovation performance of sports organizations. Second, it analyses the correlation between sports innovation and economic growth based on the literature review. Lastly, it investigates the innovative efforts and economic contributions of four Hungarian football clubs, supported by in-person interviews with their representatives conducted in 2024.

3.1 Hungarian football clubs: innovation performance

The research focused on four Hungarian football clubs: ETO FC Győr, Gyirmót FC, Mosonmagyaróvári TE, and Üstökös FC, analysing their approaches to green innovation and sustainable performance. ETO FC Győr, established in 1904, is one of Hungary's most successful clubs, with a strong history in the top tier until 2015. After facing bankruptcy, it was rescued in 2015 and aimed to return to the first division. Following a runner-up finish in 2024, it will compete in the first division for the 2024/2025 season. Gyirmót FC Győr, also located in Győr, is the second most successful club in the area and plays in the second division. Üstökös FC focuses on developing young talent, providing training for athletes aged 5 to 19, while its partner, Bácsa FC SE, offers adult championships. Credobus Mosonmagyaróvári TE, founded in 1904, will start the 2024/2025 season in the third division after finishing last in the previous season.

Table 1: Main characteristics of the Football Clubs: Innovation and performance

Innovation	Performance
Sustainable development strategy	– None of the Football clubs has its own sustainable development strategy. However, both cities Győr and Mosonmagyaróvár, have their sustainable urban Development Strategy, which includes sustainable development objectives and measures in the fields of green innovation, digitalization, a resilient and competitive economy, energy efficiency in buildings and mobility, and the use of renewable energy sources.
Management innovation and knowledge management	– The Hungarian Football Association offers continuous training and education for management and employees, focusing on grassroots football across various forms, including children's, adults', veterans', futsal, disabled, and women's games. It provides club development training to maintain the quality of Talent Centres and District Centres and offers sports, health, and science courses. The Sports Health and Sports Science training emphasizes athlete health preservation and development. Additionally, the Coaching Training Institute provides education for football trainers, goalkeeper trainers, futsal trainers, and fitness coaches. The association also offers adult training to prepare participants as professionals who align with its values and can effectively contribute to domestic clubs.
Sport innovation	– In recent years, there has been a significant change in the training planning of athletes. A range of software and sports tools support both the trainers and the athletes. All the examined clubs use "Talent X" software. The software

Innovation	Performance
Stakeholders engagement R & D Expenditures	helps organize the data on the players and monitor their performance and the team's performance. Professional work can be tracked, and valuable statistics can be prepared in just a few steps. – Another popular but pretty expensive tool is the "CATAPULT" system, used only by the most prominent clubs such as ETO FC. CATAPULT GPS (outdoor) and CATAPULT LPS (indoor) professional movement tracking systems developed to analyse sports movements enable accurate evaluation of training or performance during matches and extensive analysis, comparison, and data organization. tool is the. – There are other but still less known but very innovative tools such as the "Nimbolo" which was developed and firstly used by the Üstökös FC. This tool targets and develops several critical skills in players, helping them to perform well and effectively on the pitch. NIMBOLO is a pioneering training tool designed to develop team sports players. The device has various features that allow players to develop various skills, such as communication and tactics, reaction speed and agility, creativity and game intelligence. – The legal changes of 2011 - which were also accepted by the European Union -they allowed profitable companies and enterprises to support spectacle team sports, such as football, with their corporate tax. This system provides benefits to sports associations and supporting companies at the same time. – For parents and supporters, the associations organize various community-shaping events every six months, such as a joint football game and a New Year's Eve celebration with various programs, commemorations, and awards. – Most of the clubs' income comes from the support of the corporate taxes of companies with the contribution of the Hungarian Football Association. Infrastructure development is mainly implemented from these two sources. In some cases, the municipality also supports the sports clubs, but this support depends on various things and changes year by year. The rest of the income comes from membership fees and is spent on operations. It was also found that most of the club's green innovation is covered by infrastructure development. Significant attention is paid to using renewable energy for lighting, heating, or cooling during the development of buildings or sports fields.

3.2 Hungarian football clubs: Contribution to the local economy

Local football clubs play a multifaceted role in bolstering the local economy through job creation, infrastructure investments, increased consumer spending, and community engagement, ultimately fostering a vibrant local economy.

Table 2: Main characteristics of the Football Clubs: Contribution to the local economy

Observation	Policy documents
Job creation	– All football clubs create direct employment opportunities for various roles, including coaching staff, administrative personnel, groundskeeping, security, and matchday operations. Additionally, they provide indirect jobs in sectors like hospitality, retail, and transportation. Furthermore Üstökös FC Győr offers their talents not only football career, but other job opportunities related to football inside and outside the organisation, through supporting their coach education and referee education.
Economic activity from matchdays	– Home games attract fans who spend money on tickets, food, beverages, and merchandise. This influx of visitors benefits local businesses, such as restaurants, bars, and shops, particularly on matchdays. The investigated clubs do not yet have a merchandising activity, but Üstökös FC Győr offers Üstökös-branded clothing for athletes and fans through its contracted sports manufacturing partner.
Infrastructure development	– Investment in sports facilities results in infrastructure improvements, such as better transportation networks, parking facilities, and additional public services. These enhancements can benefit the entire community, not just football fans.
Sponsorship and investment	– Local clubs often engage with businesses through sponsorship deals, which can inject capital into the local economy. These sponsorships may provide businesses with visibility while generating additional revenue for the clubs.
Community Engagement and Development	– Many football clubs engage in community outreach programs, promoting health, education, and social cohesion. These initiatives contribute to the social fabric of the area, enhancing community well-being and engagement. Gyirmót FC Győr offers its facilities for public use free of charge through various charitable activities, including family days and municipal and entrepreneurial programs.
Sports Tourism	– Clubs with rich histories and traditions can attract sports tourists who are interested in experiencing matches or stadium tours, further stimulating local economic activity. Gyirmót FC Győr offers training camps for domestic and international clubs by its own built sports hotel.

Observation	Policy documents
Youth Development Programs	– Local clubs often run youth academies that invest in young talent, providing training and development opportunities. This contributes not only to personal development for the youth but can also lead to the emergence of future talent for local teams or even professional leagues. Mosonmagyaróvári TE and Gyirmót FC Győr have a Talent Centre role in the region. Üstökös FC Győr is in the District Centre position.
Local Identity and Pride	– The presence of a local football club can foster community identity and pride, encouraging residents to support local initiatives and contribute to the economy through various activities and spending.

4 Conclusions

This study underscores the vital link between sports innovation and economic growth in Hungarian football. Innovation provides a competitive edge essential for the sustainable development of sports organizations and their communities. By examining strategies used by Hungarian clubs, the research shows how technological progress, knowledge management, and sustainable practices enhance performance and stimulate economic activity. The findings indicate that football clubs create jobs, boost local businesses through matchday revenues, and promote community engagement via outreach programs. Case studies of ETO FC Győr, Gyirmót FC Győr, Mosonmagyaróvári TE, and Üstökös FC illustrate their roles in fostering community pride and local identity. As Hungary advances within the global sports landscape, policymakers and sports managers should prioritize innovation and sustainability.

Embracing the synergy between sports innovation and economic development benefits the sports sector and promotes the prosperity of wider communities.

Additionally, the study highlights how innovations—from digital tools to green infrastructure—align with ESG frameworks by promoting environmental sustainability, social inclusion, and good governance. The transformative potential of digital initiatives like data analytics and GPS tracking further advances performance and sustainability.

Overall, strategic innovation emerges as a crucial driver for long-term growth, inspiring policies integrating sustainability, digital transformation, and responsible governance in Hungary's sports industry.

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Sport Development via Sustainable Urban Land Use - The Case of Győr, Hungary

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This study presents an overview of the key sports developments in Győr over the past decade, emphasizing the significance of sustainable urban land use, particularly in the context of brownfield rehabilitation and comprehensive city development. Sustainable land use plays a crucial role in influencing economic, social, and environmental dynamics and aligns with the European Union's goal of achieving no net land take by 2050. In Hungary, this objective is also part of the national development strategy. Recent legislative changes, including the Architecture Act XXIII of 2023 and impending regulations for Spatial Planning and Building Requirements, underscore the focus on brownfield rehabilitation and the protection of green spaces. The paper discusses notable sports developments in Győr as well as those in other European cities, such as London and Paris. It explores the challenges faced by various investment types and identifies future opportunities for sustainable urban land use. Additionally, the study aims to highlight the social, economic, and environmental aspects of these sports investments.

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1 Introduction

Brownfield rehabilitation planning is increasingly recognized as a vital component of sustainable development in the European Union and Hungary. This approach integrates economic, social, and environmental dimensions, enhancing land use as both a catalyst and reflection of urban development. The revitalization of underutilized and contaminated sites is crucial not only for local progress but also for broader environmental sustainability, directly aligning with EU policy. Redeveloping these sites allows municipalities to transform neglected areas into economically, socially, and environmentally viable spaces. Projects may include residential neighborhoods, commercial centers, innovation parks, sport and recreational spaces, addressing urban developmental deficits. In Győr, several successful brownfield revitalization initiatives have transformed former industrial zones into vibrant areas that meet residential and commercial needs.

2 Theoretical Background / Literature Review

The term "brownfield" originated in North America and refers to land that has been abandoned or under-utilized, often due to contamination from previous industrial activities. Redeveloping these sites transforms neglected industrial, commercial, or military properties into economically, socially, and environmentally sustainable spaces through targeted revitalization efforts (Jacek et al., 2022).

The concept of brownfield is central to various European programs, emphasizing its role in combating urban sprawl and improving land use efficiency. The EU's 7th Environmental Action Program aims for no net land take by 2050, underscoring the importance of prioritizing brownfield rehabilitation.

Historically, the Olympic Games have predominantly been hosted by wealthy, industrialized nations. However, the International Olympic Committee (IOC) has recently encouraged bids from emerging economies, evidenced by the awarding of the 2008 Summer Games to China and the 2016 Games to Brazil. Such trends have raised important considerations about how host nations utilize mega-events to promote infrastructure development and overall economic growth. Focusing on previous investments in brownfield development related to the Olympic Games in cities like London and Paris offers insight into effective strategies employed by host

nations. For instance, the 2012 London Olympics involved significant redevelopment of the East London area, transforming the abandoned industrial site of the Olympic Park, which now serves as a vibrant community and sporting hub. Similarly, Paris plans to use the 2024 Olympic Games as a catalyst for substantial urban redevelopment, enhancing public transport infrastructure and repurposing former industrial sites into recreational and residential areas (Baumann et. al. 2013).

Since 1997, Hungary has established a legislative framework for brownfields, with the Act LXXVIII of 1997 providing essential definitions and emphasizing the need for focused rehabilitation. Recent updates have heightened attention on brownfield planning, aligning city development plans in Győr with sustainable urban growth objectives. Over the past 30 years, numerous abandoned sites have been repurposed, with approximately 11 former industrial and military sites now successfully utilized as sport or recreational areas, reflecting Győr's commitment to sustainable urban development.

3 Methodology

This study employs a two-step analytical process to assess the brownfield redevelopment ecosystem in Győr, Hungary, with a focus on sustainable urban development and sport-related investments.

In the first phase, a comprehensive review of European and Hungarian national policy frameworks is conducted to identify past, present, and future legislative measures related to brownfield rehabilitation. This context establishes how policies influence local development initiatives, particularly in enhancing sports facilities and community recreational opportunities.

The second phase analyzes the specific challenges and opportunities of brownfield redevelopment in Győr, emphasizing the transformation of former industrial sites into vibrant sports and recreational areas. This phase also evaluates the impacts of new legal frameworks on sustainable urban development, particularly in facilitating investments in sports infrastructure.

Through this methodology, the study aims to highlight how brownfield redevelopment can drive sustainable urban goals while promoting community-oriented sporting events.

3.1 EU legislative framework

The analysis of EU documents regarding brownfield rehabilitation reveals several important consequences that can shape future policies and strategies. While 18 documents reference brownfields, only four—such as the Circular Economy Action Plan (European Commission, 2020a) and the EU Biodiversity Strategy for 2030 (European Commission, 2020d)—explicitly address rehabilitation. This highlights a significant gap, indicating the need for more targeted policies. The limited focus on brownfields also suggests a lack of coordinated strategies across member states. Developing comprehensive frameworks can encourage the consistent application of best practices in urban redevelopment. Furthermore, the necessity for targeted brownfield policies may stimulate discussions on increasing funding through initiatives like the Just Transition Fund (European Parliament, European Council, 2021a), thereby supporting local efforts in site revitalization. Moreover, the analysis emphasizes the importance of integrating brownfield redevelopment into broader urban planning strategies, promoting both economic growth and sustainable land use. By fostering collaboration among stakeholders and highlighting successes documented in frameworks such as the European Green Deal (European Commission, 2019b) and the EU Soil Strategy for 2030 (European Commission, 2021a), the EU can enhance knowledge sharing and capacity building in brownfield management. Overall, addressing these issues positions the EU to strengthen its approach to brownfield rehabilitation, aligning with sustainable development goals while enhancing urban resilience (Szakonyi & Frank, 2024).

3.2 Hungarian legislative framework

Since 1997, Hungary's national legal framework has provided a clear definition of brownfield sites. The Building Act LXXVIII of 1997 defines brownfield land as parcels that have been abandoned, underutilized, or degraded—typically polluted due to prior industrial, commercial, transportation, or defense uses—but that can be transformed into areas of value-added development through environmental remediation and technical intervention. Came to force from October 1, 2024, the

Hungarian Architecture Act XXIII of 2023 replaced the Building Act LXXVIII of 1997. This new legislation not only reaffirms the definition of brownfield sites but also establishes the principle of prioritizing their redevelopment. It stipulates that if a brownfield site exists within a 5 km radius of the proposed new development within a municipality's administrative area, new development areas may only be designated in cases of significant public interest. Additionally, it delineates the national boundaries for brownfield areas and mandates that information pertaining to properties classified as brownfields, along with related governmental decisions, must not contain personal data. The utilization of brownfield sites must take precedence over greenfield developments, particularly when projects can be feasibly developed on brownfields. To encourage this transition, the legislation advocates for tax exemptions linked to remediation efforts and the establishment of specific urban planning, parceling, and construction requirements. Brownfield areas should be repurposed in ways that align with urban development goals and the overall urban structure, ensuring adequate provision of both technical and green infrastructure. Another significant legislative change occurred with the replacement of Government Decree 253/1997 (XII.20.) on National Urban Planning and Building Regulations by Government Decree 280/2024 (IX.30.) on the Basic Rules of Urban Planning and Building Regulations. This decree clarifies urban planning and building requirements while establishing specific regulations for the use of brownfield areas. Moreover, according to the 21/2016 (IX.23.) Municipal Decree on Győr's Master Plan, brownfield developments are positioned to play a critical role in Győr's urban development concept and strategy, as well as in its overall urban planning processes.

4 Discussion

In Győr, structural changes in the economy began in the years leading up to the political transition, marked by the decline and closure of numerous industrial enterprises, as well as their transformation. This process accelerated following the political transition, resulting in the shutdown of most producer cooperatives and the vacating of barracks formerly utilized by Russian forces. Consequently, this led to the emergence of significant brownfield areas related to the city's scale. Over the approximately 30 years since the transition, many previously abandoned buildings and brownfield sites have gradually been repurposed and redeveloped. To date, around 11 former industrial and military sites (Table 1) have undergone successful

reutilization, reflecting a growing commitment to sustainable urban development within Győr.

Table 1: Brownfield developments of the last decade

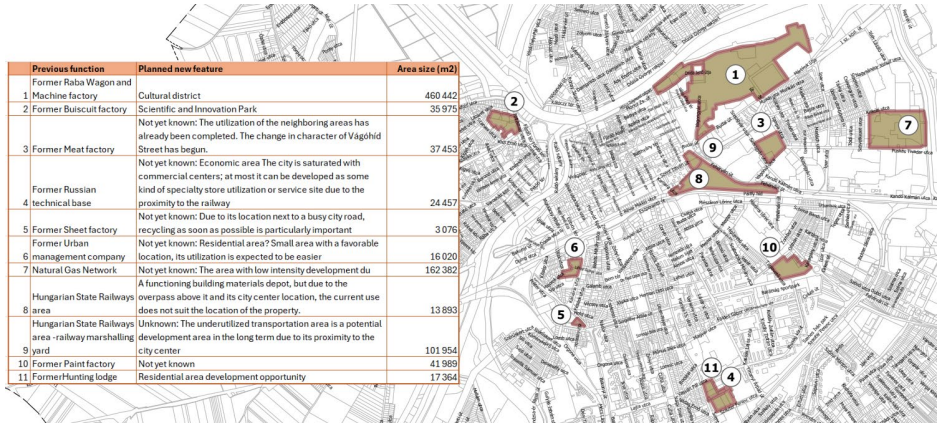
Previous function	New function
1. Former Wagon Factory 2. Former oil Factory 3. Former construction site 4. Brownfield next to Pápai st. 5. Former Frigyes Barack 6. Former hunting lodge 7. Gas centre 8. Former "Richard's" factory 9. Former textile mills 10. Former "Gardénia" curtain factory 11. Former "Graboplast" plastic factory	1. "Városrét" residential area and "Árkád" shopping mall 2. EYOF'17, Olympic village and after residential area 3. Lidl shopping center 4. Residential area 5. Leier business center 6. Neighborhood sub-center, trade services 7. "Örömhír" Primary School 8. Operational industrial estate 9. Győr Shopping Mall Center 10. „Duna" shopping centre 11. Aldi shopping center

The revitalization of the former oil factory in Győr was strategically planned in advance of the European Youth Olympic Festival. The site, transformed into the Olympic Village, exemplifies successful brownfield redevelopment, as the facilities created during this event were later converted into residential apartments for the community. Additionally, other sports facilities, including tennis courts and an athletic center, were established on former brownfield sites throughout the city. This sport-related urban development not only provided essential recreational amenities but also represents a sustainable solution, integrating environmental rehabilitation with community needs and enhancing Győr's overall urban landscape. The demolished but not yet redeveloped former industrial sites stand out like structural scars in the city strcucture. Therefore, an important task for improving the environmental quality of the city is the prompt reutilization of these areas.

5 Results

At the moment another 11 brownfield sites awaiting development (Figure 2). Although the redevelopment of the former Győr Biscuit and Wafer Factory has already commenced, where the Széchenyi University Scientific and Innovation Park is planned to be established in the near future. The former areas of the Wagon and Machine Factory have long awaited their new function. The city previously planned a Cultural Quarter with recreational areas for this substantial abandoned site.

Although many of these neglected areas currently lack a designated new function, urban development concepts are aimed at promoting sustainable growth in the city by establishing urban sub-centers and further developing green, sports, and recreational areas, paving the way for functional transformations in the future.



	Previous function	Planned new feature	Area size (m2)
1	Former Raba Wagon and Machine factory	Cultural district	460 442
2	Former Buiscuit factory	Scientific and Innovation Park	35 975
3	Former Meat factory	Not yet known: The utilization of the neighboring areas has already been completed. The change in character of Vágóhíd Street has begun.	37 453
4	Former Russian technical base	Not yet known: Economic area The city is saturated with commercial centers; at most it can be developed as some kind of specialty store utilization or service site due to the proximity to the railway	24 457
5	Former Sheet factory	Not yet known: Due to its location next to a busy city road, recycling as soon as possible is particularly important	3 076
6	Former Urban management company	Not yet known: Residential area? Small area with a favorable location, its utilization is expected to be easier	16 020
7	Natural Gas Network	Not yet known: The area with low intensity development du	162 382
8	Hungarian State Railways area	A functioning building materials depot, but due to the overpass above it and its city center location, the current use does not suit the location of the property.	13 893
9	Hungarian State Railways area -railway marshalling yard	Unknown: The underutilized transportation area is a potential development area in the long term due to its proximity to the city center	101 954
10	Former Paint factory	Not yet known	41 989
11	FormerHunting lodge	Residential area development opportunity	17 364

Figure 1: Brownfield development sites near the city center of Győr

6 Conclusions

The case of Győr, Hungary, exemplifies the transformative potential of sustainable urban land use, particularly through the redevelopment of brownfield sites into vibrant sports and recreational areas. This study has outlined the city's strategic approach to revitalizing neglected industrial spaces, aligning with both local needs and broader European sustainability goals. Recent legislative frameworks, such as the Architecture Act XXIII of 2023, emphasize the importance of prioritizing brownfield rehabilitation, thereby paving the way for significant economic, social, and environmental benefits. Through targeted investments and comprehensive urban planning, Győr has successfully repurposed several former industrial sites, as evidenced by the establishment of facilities for the European Youth Olympic Festival and the conversion of these spaces into residential and community areas. This integration of sports development into urban design not only addresses the legacy of industrial decline but also enhances community cohesion, promotes health and well-being, and contributes to environmental sustainability. However, as Győr continues to navigate the challenges of redevelopment, it is essential to maintain momentum in addressing the remaining brownfield sites without designated

functions. Future urban planning should focus on transforming these areas into functional spaces that support both recreational activities and green infrastructures, ensuring a sustainable urban landscape for generations to come. By fostering collaboration among stakeholders and adhering to EU directives, Győr stands as a model for other cities aiming to leverage brownfield rehabilitation as a catalyst for sustainable development in sport and beyond.

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Comparative Analysis of the Regional Operation of the Just Transition Fund Based on Territorial Development Plans and Best Practices

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As a new instrument of Cohesion Policy, the Just Transition Fund (JTF) was introduced in the 2021-2027 programming period, which is the part of the European Green Deal. Its main goal is to make the European Union climate-neutral by 2050. The JTF supports regions with high carbon emissions, and its aim is to manage industrial transition and structural change. The study examines how each region is implementing its Just Transition Fund plans and what innovative funding systems have been developed. In addition, through secunder research, we present model projects that are moving towards a circular economy and economic diversification and are relevant to the regions concerned. Three similar coal regions have been highlighted (Hungary - Baranya County, Czech Republic - Ústí Region, Spain - Asturias Region), which show similar economic and social symptoms. Each of the three regions has approached the problem with very different operational programmes and draft calls for proposals, resulting in different pull projects to support their economies. The aim of the study is to prove the hypothesis that, despite the similarities in the economic environment, programmes can be successfully implemented along the lines of the expected effects of the Just Transition, even under different support schemes.

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1 Introduction

The **Just Transition Fund (JTF)** was established by the European Union to support regions disproportionately affected by the transition toward a climate-neutral economy (European Commission, 2024a) within the 2021-2027 programming cycle, to slow down climate change The JTF is the first pillar of the Just Transition Mechanism, which is part of the European Green Deal (European Commission, 2024b), and its primary goal is to enable the European Union to achieve climate neutrality by 2050. The Just Transition Mechanism (JTM) consists of three pillars (European Commission, 2024c):

- The Just Transition Fund (European Parliament and Council, 2021a),
- A dedicated Just Transition scheme within the InvestEU program (European Union, 2024a).
- A public sector loan facility in cooperation with the European Investment Bank (EIB) (European Investment Bank, 2024).

Compared to previous support mechanisms linked to the European Green Deal, the Just Transition Mechanism introduces an entirely new approach. It does not solely focus on the industrial transition of regions dependent on fossil fuels and/or regions with high ETS (European Union Emissions Trading System) emissions. Instead, it also seeks to mitigate the negative social, economic, and environmental impacts of climate neutrality measures through local interventions, combining grants and loan-based financial support—not only for the private sector but also for the public sector.

"The EU ETS is a key element of the EU's climate action, aimed at reducing greenhouse gas (GHG) emissions in a cost-effective manner." (Publications Office of the European Union, 2024).

The Just Transition Fund supports regions that, for specific reasons, have particularly high carbon dioxide emissions. To prevent regional disparities and in line with the objectives of the EU's Cohesion Policy, the fund aims to facilitate industrial transition and manage structural changes across all sectors, including transportation, energy, agriculture, the built environment, and industry.

Regions applying for support must demonstrate that their economies are heavily dependent on fossil fuels (such as lignite, coal, peat, oil shale, heavy oil, or diesel) and/or engage in carbon-intensive industrial activities (e.g., cement production). While the Just Transition Fund does not directly finance the transition to climate neutrality, it contributes significantly to its achievement.

In each country, the selection of the affected NUTS3 regions was based on statistical analysis and an assessment of which areas are most impacted by carbon dioxide emissions. This impact stems partly from coal and fossil fuel extraction, their use in power plants, or high ETS (Emissions Trading System) emissions. The assessment also included mapping potential economic and social challenges in the affected areas, taking employment, economic, and environmental indicators into account.

We examined three coal regions struggling with similar fundamental problems, based partly on their Just Transition Territorial Plans and partly with the assistance of experts involved in local planning. All three regions have been classified by the European Union as less developed regions under Article 108 (European Parliament and Council, 2021b), meaning that, in addition to coping with the transition to climate neutrality, they also face challenges arising from their weaker economic conditions (Hungary – Baranya County, Czech Republic – Ústí Region, Spain – Asturias Region). These areas were coal regions before the 1990s, with economies based on lignite mining.

2 Theoretical Background / Literature Review

The Just Transition Fund (JTF), established by the European Union, aims to provide targeted support to those regions that are disproportionately affected by the transition to a climate-neutral economy. This study explores how selected regions are implementing their respective JTF strategies, what innovative funding mechanisms they apply, and which model projects support the shift toward a circular economy. The research is based on secondary sources—including program documents, operational plans, and policy analyses—and uses a comparative approach to present the transition processes of three coal-dependent regions with similar characteristics: Baranya County (Hungary), the Ústí Region (Czech Republic), and the Asturias Region (Spain).

It falls within the competence of the national government to designate which institution participates in regional policy-making, and to determine the degree of involvement granted to subnational actors in the planning and implementation of development programs. Consequently, despite the strict regulatory framework of the European Union, the institutional structures of territorial development vary significantly across member states. These differences are closely linked to each country's political and administrative systems, as well as to historically embedded institutional traditions (Kengyel, 2016).

Although the three countries began from comparable economic and social baselines, they adopted divergent planning mechanisms to approach the program (Huba-Varga N., Pongrácz A. Zádori I., 2025). The three regions share several characteristics: the gradual decline of previously dominant coal and heavy industries, aging infrastructure, high unemployment rates, and low entrepreneurial activity. The aim of this study is to demonstrate that although the socioeconomic context of these regions provides a similar starting point, their respective operational programs offer different responses to the challenges—yet all show evidence of the potential success of a just transition.

Each of the three regions examined has developed its own development strategy and JTF-related priority axes. These different financial mechanisms - calls for proposals, indirect public support schemes, or even public risk capital funds - have been tailored to the region. This underpins the objective of EU cohesion policy to reduce territorial disparities while providing opportunities to test innovative, local intervention models. In each of the three regions, projects aimed at circularising the economy can be identified. Strong institutions and sound governance correlate with higher fund uptake, whereas political instability or weak administration hinder performance. The importance of institutional frameworks in program implementation across Europe are high (Incaltarau, C., Pascariu, G. C., Surubaru, N.-C. 2020).

3 Methodology

Each of the selected countries has integrated the **Just Transition Fund (JTF)** into its operational programming framework in a distinct manner. The analysis is based on the review of **region-specific Operational Programs**, from which the planned

types of interventions, their respective target groups, and the anticipated impacts of these measures were examined.

In **Hungary**, the JTF is not implemented through a stand-alone operational program. Instead, it is embedded as a **specific priority axis within the existing Environment and Energy Efficiency Operational Program Plus (KEHOP Plusz).** Within this framework, dedicated calls for proposals are designed to support transition-related activities. The Hungarian JTF-supported measures aim to promote **economic diversification**, foster **job creation**, enable the **re-skilling of workers**, and support the development of **environmentally sustainable technologies and infrastructures** in the affected regions.

In **Spain**, the Just Transition Fund is implemented through a **dedicated, stand-alone operational program**. In accordance with **EU Regulation 1060/2021**, the **Managing Authority** is the Directorate-General for European Funds under the Ministry of Finance. In the **Asturias Region,** an administrative unit linked to the **Regional Ministry for Ecological Transition, Industry, and Economic Development** operates as an **intermediate body** responsible for the implementation of the JTF Operational Program in that territory.

In **the Czech Republic**, the JTF is also implemented through a **dedicated operational program,** namely the **Spravedlivá transformace Operational Program (OPST).** This program was specifically established to support regions most severely impacted by the transition away from a coal-based economy, including **Ústí nad Labem, Karlovy Vary**, and the **Moravian-Silesian** regions. The OPST sets out a coherent framework for project selection and investment focused on regional restructuring, job creation, environmental restoration, and innovation-driven development.

4 Results

Hungary (Baranya County)

In Hungary, the Just Transition Fund (JTF) is integrated into the national system as part of the Environmental and Energy Efficiency Operational Programme Plus (KEHOP+). Unlike other Member States, no separate regional chapters were

created for each affected county. Priority Axis 5 addresses the social and economic impacts of the transition to climate neutrality, targeting the counties of Baranya, Heves, and Borsod, which are most exposed to these changes.

Although its focus is socio-economic, the priority also contributes to reducing greenhouse gas emissions. It supports a wide range of interventions, including economic diversification, environmental rehabilitation, and workforce reskilling. Key intervention types include:

- **Innovation and technology transfer**
- **Energy efficiency in enterprises**
- **Renovation of residential buildings**
- **Smart energy systems and storage**. Developing smart grids and energy storage solutions (e.g. hydrogen, battery systems).
- **Brownfield rehabilitation**. Cleaning up and repurposing contaminated former industrial areas.
- **Labour market adaptation**. Supporting reskilling and job transition for workers affected by the phasing out of fossil fuels.

Target groups include SMEs, workers in carbon-intensive industries, municipalities, research institutions, energy sector actors, and households. (Hungarian Government, 2022)

Spain (Asturias Region)

Asturias has its own regional priority under Spain's stand-alone Just Transition Programme (Programa Transición Justa 2021–2027). The programme addresses the socio-economic and environmental consequences of the climate transition, with a focus on promoting economic diversification, job creation, renewable energy deployment, and social cohesion.

Key thematic intervention areas include:

- Digital transformation (e.g., SME digitalisation, e-commerce)
- Business development (e.g., internationalisation, productivity)

- Renewable energy (solar, biomass, energy efficiency)
- Environmental remediation (polluted sites)
- Education and employment (reskilling, infrastructure)
- Sustainable tourism and heritage preservation

Asturias was allocated €115.1 million in JTF funds, making it one of Spain's largest regional envelopes. Funding is co-financed at 50% by the EU and complemented by national sources. Most support is provided as non-repayable grants, with future use of financial instruments also foreseen. (Ministry for Ecological Transition and the Demographic Challenge Spain, 2021)

Czech Republic (Ústí Region)

In the Czech Republic, the Just Transition Programme 2021–2027 operates as a separate OP, with distinct priorities for coal regions such as Ústí nad Labem. Priority 2.1 addresses the negative impacts of coal phase-out, focusing on employment transitions, economic restructuring, and territorial rehabilitation. Priority areas of intervention:

- Economic diversification (innovation, SME growth)
- New energy technologies (hydrogen economy, renewables, battery production)
- Land rehabilitation (post-mining areas)
- R&D and digital transformation
- Circular economy and waste management
- Education and social inclusion

Support also targets hydrogen infrastructure, lithium-based battery production, energy communities, digital applications, creative industries, and green infrastructure.

Main target groups include SMEs (particularly in energy, chemicals, glass/ceramics), affected workers (through reskilling and support services), public institutions, and vulnerable communities.

Ústí region is allocated over €232 million from the JTF and national co-financing, enabling the implementation of regionally tailored transition strategies. (Ministry of the Environment Czech Republic, 2021)

5 Discussion

The Just Transition Fund (JTF) programming architecture across the three examined countries—Hungary, Spain, and the Czech Republic—reveals notable differences stemming from institutional design, the degree of decentralisation, and the capacity for regional differentiation. In Spain and the Czech Republic, the JTF is implemented through standalone operational programmes. Within these, individual regions—such as Asturias in Spain and Ústí nad Labem in the Czech Republic—possess dedicated priorities and earmarked budgets. This structure facilitates alignment between programming and the socio-economic characteristics of each region, enables region-specific performance tracking, and allows for greater flexibility and strategic revision when needed. It also guarantees that financial resources remain within the designated territories, thereby strengthening the role of regional actors in programme execution.

In contrast, Hungary has opted to integrate the JTF into an existing operational programme—the Environmental and Energy Efficiency Operational Programme Plus (KEHOP+), under Priority Axis 5. Within this framework, the three concerned counties (Baranya, Heves, and Borsod-Abaúj-Zemplén) do not have separate budgetary lines or priority structures. As a result, interventions follow a uniform programme logic, limiting the ability to tailor actions to specific territorial needs. One critical limitation of this approach is the lack of modularity; should regional programme modifications become necessary, adjustments can only occur by amending the entire priority axis.

Overall, the Spanish and Czech approaches provide regions with greater programming autonomy, enhancing the effectiveness of the JTF by allowing for a better fit with local transition challenges—such as economic diversification, the social implications of phasing out coal, and sustainable labour market transformation. The Hungarian model, by contrast, offers less flexibility and may be less responsive to local variance, which could undermine the programme's impact in terms of territorial justice and targeted socio-economic resilience.

6 Conclusions

The findings of the comparative analysis provide strong empirical support for the initial hypothesis that, although the selected regions—such as Baranya (Hungary), Ústí nad Labem (Czech Republic), and Asturias (Spain)—share broadly similar socio-economic legacies rooted in the decline of coal-dependent industries, the implementation of regionally differentiated programming approaches does not obstruct, but rather enables the successful realisation of the overarching objectives of the Just Transition Fund (JTF). In fact, the observed variance in the design and governance of JTF interventions across the cases reinforces the proposition that context-sensitive policy frameworks can be more effective than uniform, top-down models in addressing the complex and territorially embedded challenges of economic and social transformation.

The study illustrates that each country has pursued its own institutional configuration and strategic logic in deploying JTF resources: Hungary embedded JTF measures within the KEHOP Plusz operational programme as a dedicated priority axis; Spain created a stand-alone operational programme at the national level with decentralised implementation in regions like Asturias; and the Czech Republic opted for a fully independent operational programme (OPST) to serve its most affected coal regions. These configurations reflect distinct administrative traditions, political economies, and multi-level governance structures, yet all demonstrate a high degree of alignment with the Just Transition's core objectives, such as decarbonisation, job creation, and the revitalisation of vulnerable territories.

Moreover, the analysis underscores the value of territorial specificity and locally adapted intervention logic as enablers of effective policy implementation. By calibrating actions to the economic profiles, social needs, and environmental conditions of their respective regions, programme authorities have been able to design project pipelines that are both technically feasible and politically legitimate. This affirms the theoretical proposition—frequently emphasised in EU cohesion policy literature—that bottom-up planning, combined with funding flexibility and multi-level coordination, enhances the responsiveness and legitimacy of structural interventions.

In sum, rather than constituting a barrier to coherent implementation, differentiated programming mechanisms rooted in local institutional contexts contribute to a more equitable and territorially just transition process. This highlights the importance of maintaining decentralised governance arrangements and ensuring that future funding cycles continue to allow for customisation and subsidiarity in programme design and execution.

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VALIDATION OF THE SHORT FORM OF THE REMOTE WORK STRESS SCALE

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Extant literature on remote work stress has yet to yield a reliable scale. This study aims to refine the previously established 5-factor, 15-item Remote Work Stress Scale into a unidimensional construct comprising 5 items. As part of the research, we conducted a survey of 602 employees in Turkey who currently actively work remotely. The results showed that the 5 item Short form of the Remote Work Stress Scale is valid (X^2/df= 4.91; RMSEA=.08; SRMR=.02; NFI=.99; NNFI=.98; CFI=.99; GFI=.99; AGFI=.95) and reliable (Cronbach's Alpha=.88; Guttman Split-Half Coefficient=.72). In addition, to examine how the Remote Work Stress Scale differs according to demographic factors, we used multiple correspondence analysis and found that remote work stress is mainly affected by the sex, education and job position. Accordingly, male employees in managerial positions, working in private companies with university or lower education experienced lower remote work stress whereas female and non-managerial employees with master or higher education experienced higher remote work stress.

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1 Introduction

Despite the growing body of research on remote work stress, there has been a lack of a reliable measurement tool specifically designed to assess this phenomenon. Remote work is defined as working outside of a traditional office setting, often utilizing information and communication technology to perform tasks and communicate with others (Beckel & Fisher, 2022). Remote work provides numerous advantages, such as flexible hours and enhanced work-life balance; nonetheless, it also entails specific disadvantages, such as isolation, increased workload, and reduced communication (Ipsen et al., 2021). Costin et al. (2023) indicate that remote workers encountered challenges related to work-life balance, emotional labor, job burnout, and daily occupational pressures.

This study aims to make a significant contribution to the existing literature by addressing two key objectives. First, it seeks to propose a valid and reliable measurement instrument for remote work stress. Second, it aims to simplify the Remote Work Stress Scale developed by the research group, which initially comprises 5 factors and 15 items, into a more concise single-factor scale. By achieving these objectives, the study intends to enhance the understanding and assessment of stress experienced by remote workers. The primary objectives of this research are to create a valid and reliable measurement instrument that accurately captures the nuances of remote work stress while also condensing the original scale into a more practical format, which aims to facilitate easier application and interpretation of the scale in various organizational contexts.

This study also aligns with the United Nations' Sustainable Development Goal 8 (SDG 8), which emphasizes the promotion of sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all (United Nations, 2015). As remote work becomes a defining element of the modern labor market, understanding and mitigating stress related to remote working conditions is crucial for ensuring both productivity and worker well-being. Elevated stress levels among remote employees can reduce job satisfaction, increase burnout, and hinder overall performance, thereby threatening the goals of decent and inclusive work environments (Eurofound, 2021; Wang et al., 2021). By developing a reliable and valid instrument to measure remote work stress, this study contributes to global efforts in advancing workplace practices that support employee mental health and

promote sustainable economic participation. Furthermore, identifying vulnerable groups who are more susceptible to remote work stress—such as women and highly educated non-managerial employees—can inform targeted interventions that reduce inequalities in work conditions and improve labor market inclusivity.

2 Methodology

For this study, we recruited white-collar employees with remote work experience through LinkedIn, inviting them to participate voluntarily. We based our sample size on the representative population size of 380 individuals at the 95% confidence level with a 5% margin of error (Sample Size Calculator, 2025; Costello & Osborne, 2005). The data collection tool consisted of two sections. The first section gathered demographic information, including gender, educational status, marital status, parental status, organizational type, job position, and age. The second section contained the 15 item, 5 factor Remote Work Stress Scale developed by the research group, which we aimed to shorten.

The study sample includes 602 participants. The majority are female (58.8%), have a master's degree or higher (52.2%), are married (55.6%), and do not have children (61.3%). Most work in the private sector (82.9%) and hold non-managerial roles (64.5%). The average age is 36 years (SD = 8).

3 Results

To develop a concise scale, we performed an exploratory factor analysis (EFA) on a suitable dataset (KMO = .92; Bartlett's Test $\chi^2 = 6576.679$, df = 105, $p < .001$). Using Principal Component Analysis and Varimax rotation, we retained items with factor loadings $\geq .40$ (Yong and Pearce, 2013), resulting in a single-factor scale comprising items s4, s5, s6, s8, s9, and s12 (loadings: .76 – .79). This factor exhibited an eigenvalue of 8.07, accounting for 53.80% of variance, surpassing the 50% threshold typical in social sciences (Beavers et al., 2013).

Table 1: Rotated Matrix Results (n=602)

Items	Mean	Standard Deviation	Factor Loadings
s1	2.82	1.30	-
s2	3.08	1.38	-
s3	3.07	1.45	-
s4	3.28	1.40	.791
s5	3.44	1.35	.767
s6	3.32	1.37	.799
s7	2.96	1.27	-
s8	3.18	1.29	.765
s9	3.16	1.33	.777
s10	2.74	1.31	-
s11	3.12	1.33	-
s12	3.00	1.30	.764
s13	3.38	1.41	-
s14	2.98	1.34	-
s15	2.66	1.37	-
Eigenvalues			8.07
% of Variance			53.80

We conducted a confirmatory factor analysis (CFA) and found that item s9 had a coefficient < .50 and a non-significant t-value (p > .05), leading to its exclusion. After re-running the CFA, the final single-factor scale comprised 5 items with coefficients ranging from .60 to .89, all significant at the 5% level (t > 1.96) (Hair et al., 2010).

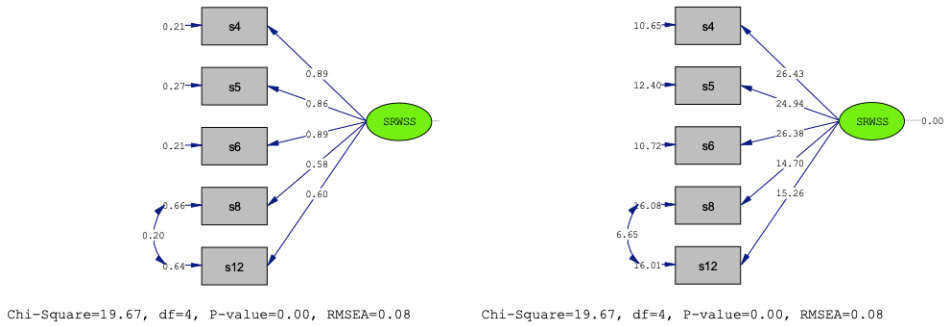


Figure 1: Standardized Coefficient Solutions and t-Values for the Scale

Goodness-of-fit indices supported an acceptable model: $X^2/df < 5$, RMSEA = .08, SRMR = .02, NFI = .99, NNFI = .98, CFI = .99, GFI = .99, AGFI = .95, validating the short-form Remote Work Stress Scale (Çömlekçi & Başol, 2019; Özkan et al.,

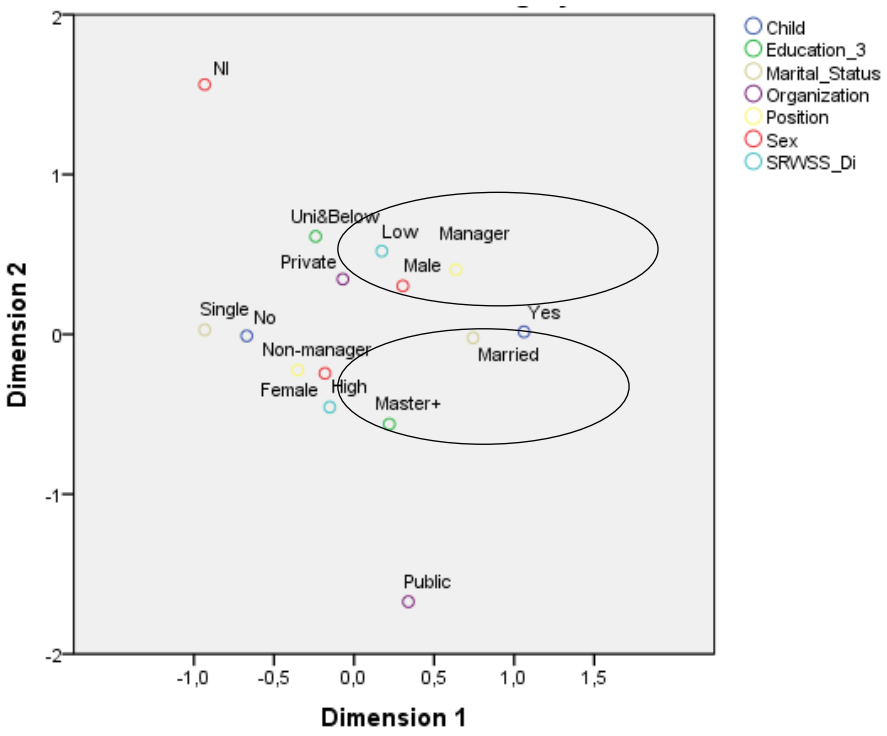
2023). Reliability metrics included Cronbach's Alpha (CA) = .88, Composite Reliability (CR) = .88 (Başol & Çömlekçi, 2022), and Average Variance Extracted (AVE) = .60 (Bagozzi & Yi, 1988). Split-half reliability showed an inter-form correlation of .64 and a Guttman Split-Half Coefficient of .72 (Talli, 2019), with corrected total-item correlations of .61–.80 (De Vaus, 2002). No item deletion improved CA beyond .88, confirming the 5-item scale's reliability (M = 3.25 ± 1.11). Correlations between the short and original forms ranged from .64 to .95, supporting its substitutability (Table 2). Psychometric evaluations affirmed the short form's validity and reliability.

Table 2: Correlations Results Between Short and Original Form

	SRWSS
SRWSS	1
WLI	.64**
OWE	.95**
MIS	.79**
INA	.77**
INS	.65**
RWSS	.93**

SRWSS= Short form of Remote Work Stress Scale; WLI = Work-Life Imbalance; OWE= Overworking; MIS= Miscommunication; INA= Inactivity; INS= Insecurity; RWSS= Remote Work Stress Scale
**p<.01

A multiple correspondence analysis (MCA) was conducted to examine typologies among demographic variables and remote work stress levels (Figure 2). When categorizing remote work stress into two groups (Low and High) and grouping demographic variables into binary categories, four main axes emerged: remote work stress, sex, education and job position. The results indicated that male employees in managerial positions, working in private companies with university or lower education experienced lower remote work stress; whereas female and non-managerial employees with master or higher education experienced higher remote work stress. This finding highlights the impact of sex, education and job position as key determinants of remote work stress.



Child= Yes, No; Education= University and Below, Master or High; Marital Status= Married, Single; Organization= Private, Public; Position= Manager, Non-manager; Sex= Female, Male; Remote Work Stress= High, Low

Figure 2: Results of the Multiple Correspondence Analysis

4 Discussion and conclusions

The main objective of this study is to shorten the Remote Work Stress Scale. The scales were shortened for several reasons, including time savings, reducing the number of behaviors measured, and creating a short form with the same validity as the long form (Koğar, 2020). Additionally, among its benefits are the ability to eliminate challenges frequently encountered in empirical studies, reduce participant burden, and provide efficiency, focus, and ease of implementation (Botes et al., 2021; Kruyen et al., 2013). It also may be convenient for longitudinal studies, does not intimidate participants when refilled at short intervals, and reduces the likelihood of being left unfinished.

This study aimed to condense the 5-factor, 15-item Remote Work Stress Scale into a unidimensional, 5-item construct. In the first phase, data from 602 remote workers were analyzed, yielding a valid and reliable shortened scale. In the second phase, Multiple Correspondence Analysis assessed the relationship between the shortened scale and six dichotomously coded demographic variables. Findings revealed that male managers in private firms with university or lower education reported lower stress, while female non-managers with master's or higher education exhibited elevated stress, highlighting the influence of gender, education, and occupational status on remote work stress.

It is imperative that policymakers consider gender-sensitive and education-specific policies when designing remote work regulations. Given that female and highly educated non-managerial employees experience higher levels of stress, governments and organizations should implement policies that promote work-life balance, mental health support, and equitable work environments. Additionally, labor laws may need to address remote work stress disparities to ensure fair working conditions for all employees.

The present study makes a contribution to the existing literature on occupational stress by providing a validated and reliable Short Remote Work Stress Scale (SRWSS). The findings also lend support to the role of demographic factors—particularly gender, educational attainment, and managerial status—in influencing remote work stress levels. Future theoretical models on remote work stress should integrate these factors to develop more nuanced frameworks for understanding workplace well-being in remote settings.

Organizations should adapt remote work policies to address stress disparities among different demographic groups. Furthermore, managers should implement targeted interventions, such as flexible work arrangements, mentorship programs, and mental health resources, to support highly educated non-managerial employees and female workers. Additionally, HR professionals can use the shortened Remote Work Stress Scale for quick and efficient stress assessments to improve employee well-being.

This study has some limitations. First, the sample consisted of remote workers from a specific demographic, organizational and country context, which may limit the generalizability of the findings. Second, the study relied on self-reported data, which

may be subject to response bias. Third, while the shortened scale was found to be valid and reliable, further validation across diverse industries and cultural settings is needed. Future research should test the shortened scale in different occupational sectors and geographical regions to enhance its applicability. Longitudinal studies can explore how remote work stress evolves over time and whether interventions effectively mitigate stress.

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The Role of Artificial Intelligence in Enterprise Resource Planning (ERP) Systems

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This study examines the role and impact of artificial intelligence (AI)-based methods in Enterprise Resource Planning (ERP) systems. ERP systems are critical tools that integrate all business processes to optimize data management. In this context, the integration of AI algorithms into ERP processes offers businesses new opportunities to accelerate decision-making mechanisms, enhance process efficiency, and optimize costs. The study elaborates on the contributions of AI in areas such as predictive analytics and process automation, presenting a strategic framework for businesses. The findings demonstrate that AI-supported ERP systems are powerful tools that increase businesses' ability to adapt to dynamic market conditions.

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1 Introduction

Enterprise Resource Planning (ERP) systems are critical tools that integrate business processes to enhance efficiency and support decision-making processes. In today's rapidly changing business environment, companies must develop data-driven and dynamic structures to maintain their competitive advantage. In this context, the integration of artificial intelligence (AI) technologies into ERP systems offers significant opportunities for businesses to manage operations more effectively, optimize processes, and make strategic decisions (Haider, 2021).

For small and medium-sized enterprises (SMEs) in particular, which constitute the backbone of many economies, AI-enabled ERP capabilities offer a chance to accelerate digital transformation despite limited resources. SMEs are widely recognized as key drivers of innovation and employment; thus, their successful adoption of advanced technologies is vital for inclusive economic growth. By harnessing AI within ERP systems, these smaller firms can overcome some of the constraints in data analysis and decision-making that stem from their scale, thereby narrowing the competitive gap between themselves and larger corporations.

ERP systems unify all operations of a business under one umbrella by integrating various processes, ranging from accounting to supply chain management. However, traditional ERP systems are limited in analyzing large and complex data sets. AI-based methods overcome these limitations, making ERP systems smarter and more autonomous (Hrischev & Shakev, 2022). For instance, predictive analytics enables forecasting future demand and sales trends, natural language processing enhances user experience, and process automation significantly reduces costs (Kunduru, 2023).

AI-powered ERP software provides numerous advantages, including integrated data management, optimized processes, real-time access, more informed decision-making, reduced operational costs, increased efficiency, high adaptability, superior customer satisfaction, and enhanced collaboration. The integration of AI and ERP systems facilitates businesses' adaptation to dynamic market conditions and plays a critical role in digital transformation processes (Sevim & Bülbül, 2017). Predictive analytics is one of the most critical advantages AI brings to ERP systems. It accelerates decision-making in processes like demand forecasting, supply chain

optimization, and cost analysis, providing businesses with a competitive edge (Sevim & Bülbül, 2017). Additionally, AI algorithms enable more effective use of the data stored in ERP systems through big data analytics, thereby contributing to businesses achieving their strategic goals.

This study explores the role of AI technologies in ERP systems, the advantages offered by these technologies, and the challenges encountered. In particular, AI applications that enhance predictive analytics, process automation, and user experience will be examined in detail. Furthermore, the strategic contributions of AI-supported ERP systems to businesses and their future potential will be evaluated. In conclusion, the aim of this study is to highlight the innovations brought by AI-supported ERP systems and the strategic advantages they offer to businesses, contributing to the literature in this field.

2 Theoretical Background / Literature Review

The integration of ERP (Enterprise Resource Planning) systems and artificial intelligence (AI) has become a prominent research area in recent years, attracting attention at both academic and industrial levels. Most of these studies broadly examine the impacts of AI-supported ERP systems on businesses. However, the lack of in-depth sector-specific analyses and the limited number of practical studies are notable shortcomings. Sevim and Bulbul (2017) made a study focusing on the use of AI algorithms in the continuous auditing of ERP systems emphasized significant benefits such as the automation of auditing processes and cost reductions. However, sectoral differences and long-term effects were not addressed. Oguz and Agtas (2024) has a study investigating the effectiveness of AI-supported ERP systems in supply chain management discussing the contributions of predictive analytics to decision-making processes. However, it lacked practical implementation. Sarnic and Acar (2024) examined the potential benefits of integrating AI into ERP systems. It did not include more specific applications. There is a study made by (Bahssas et al., 2015) addressing innovative approaches in ERP systems and future AI trends presented a theoretical framework but often lacked application details. (Jin et al., 2022) has a study exploring the role of AI in the accounting module and the benefits of automation discussed improvements in financial processes but did not address applicability in different industries.

Although the existing literature provides valuable insights into AI-supported ERP systems, there are significant gaps. First of all, examining the impacts of AI-supported ERP systems across different industries is missing. Secondly, there are not many studies analyzing how small and medium-sized enterprises (SMEs) can benefit from AI technologies. Finally, investigating the long-term effects of ERP and AI integration and their contributions to digital transformation processes is not thoroughly mentioned.

This study not only aims to fill these gaps in literature but also explains how modern AI techniques, such as predictive analytics, natural language processing (NLP), and deep learning, can be used within ERP modules. Overall, this study highlights the potential of AI and ERP integration in the business world from both academic and industrial perspectives and sheds light on future research.

3 Methodology

The integration of artificial intelligence (AI) into Enterprise Resource Planning (ERP) systems has become a transformative element that elevates organizational efficiency and performance. This section discusses the role of AI in ERP systems and the applicable methods. Figure-1 illustrates various use cases and functions of AI integration in ERP systems.

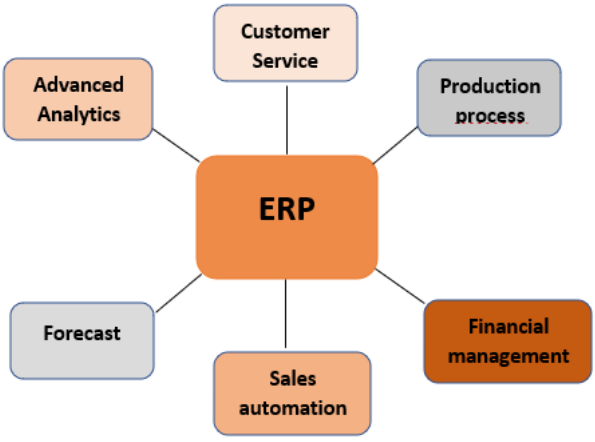


Figure 1: ERP Tools

3.1 Use of Artificial Intelligence in Customer Services

AI-based applications such as chatbots, digital assistants, and automated response systems significantly contribute to improving customer satisfaction while reducing operational burdens. Specifically, natural language processing (NLP) technologies excel in understanding customer demands and offering appropriate solutions. For example, in the banking sector, AI-based assistants offer a wide range of services, from credit applications to customer account inquiries (KORUMAZ, 2023); (İşeri et al., 2021). The use of AI in customer services not only improves operational processes but also enables businesses to build stronger connections with their customers. These systems enhance customer satisfaction while providing businesses with a strategic competitive advantage (Hargreaves et al., 2018; Li & Xu, 2022).

3.2 Optimization in Production and Inventory Processes

AI technologies integrated into Enterprise Resource Planning (ERP) systems enable businesses to streamline their operations through real-time data analytics. Walmart improves product projections by utilizing advanced computer vision and machine learning technologies. In order to monitor the stock in real time and automatically alert Walmart and its suppliers when their products are sold out, they receive data from the robotic shelf scanner in addition to numerous other data signals. This allows them to replenish their stores more quickly (Mostafa, 2020). AI algorithms plan production processes, reducing raw material lead times and costs. In supply chain management, AI contributes to improving logistics processes (Turgut, 2023). Moreover, the predictive analytics capabilities of AI algorithms allow businesses to anticipate supply chain disruptions and take proactive measures (Yazılım, n.d.).

3.3 AI-Supported Automation in Financial Management

AI strengthens financial management processes by being utilized in credit risk analyses and investment decisions (Masraff, n.d.). Advanced data analytics and machine learning algorithms monitor and report unusual financial transactions in real time, simplifying audit processes. For example, AI-supported ERP systems can quickly identify fraud risks by analyzing large volumes of financial data and improve regulatory compliance (ÇETİN & TİRYAKİ, n.d.). AI-supported ERP systems are redefining the standards of efficiency and accuracy in financial management. These

technologies play a crucial role in helping businesses achieve their digital transformation goals, creating significant value for both large-scale enterprises and small to medium-sized businesses (Kestane & Kurnaz, 2019).

3.4 Use of Advanced Analytical Methods

Predictive analytics tools not only analyze existing data but also offer insights into future market trends, creating significant opportunities for businesses to gain a competitive advantage (Perçin & cansu Gök, 2013). In particular, advanced analytical methods enhance operational efficiency in supply chain and production management. AI is utilized to optimize logistics processes, predict delays, and evaluate supplier performance (Rezki & Mansouri, 2024). The integration of advanced analytical methods into ERP systems not only facilitates data analysis processes but also strengthens strategic decision-making. Big data analysis and predictive modeling significantly contribute to businesses gaining a competitive edge and achieving long-term success (SAP., n.d.).

3.5 Sales Automation and Forecasting

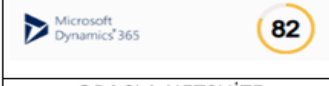
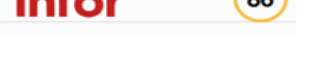
AI-supported ERP systems analyze customers' purchase histories and habits, making cross-sell and up-sell strategies more effective (Çelebi & Bulut, 2016). AI-supported ERP systems support businesses in making strategic decisions by predicting market trends. For instance, an automotive manufacturer could use AI algorithms to analyze regional sales trends and determine which markets to prioritize. Furthermore, machine learning applications such as price elasticity analysis allow businesses to optimize product pricing according to market dynamics (Ranganathan et al., 2024). In sales management, AI-supported ERP systems not only improve operational processes but also provide businesses with strategic advantages that enhance profitability. These technologies enable businesses to better evaluate future sales opportunities while increasing customer satisfaction (Düzelten, n.d.).

4 Results

The findings indicate that AI-driven ERP systems significantly enhance business efficiency by automating routine processes, improving decision-making, and optimizing resource allocation. AI-powered ERP software offers advantages such as

real-time data analysis, demand forecasting, and cost reductions, making enterprises more adaptable to market fluctuations.

Table 1: Analyst Evaluations of ERP Software in 2024 (Hari, 2025)

ERP SOFTWARE	ADVANTAGES OF ERP SOFTWARE
ORACLE 	• Modern interface • Wide range of features • Scalability and flexibility • Integration with Oracle products • Security and compliance
SAP S4 HANA 	• Scalability • Real-time information • Mobile access • Streamlined workflows • Less maintenance
ACUMATİCA 	• Flexible and customizable • Scalable • Mobile access and user-friendly • Powerful features and integrations • Strong community support
MS DYNAMİCS 365 	• User-friendly interface • Flexible customization • Seamless integrations • Powerful analysis tools • Scalability
ORACLA NETSUİTE 	• Enhanced visibility • Easy to use • Real-time data • Scalability and flexibility
İNFOR 	• Scalability and flexibility • Security • Global solution • Supports core business processes • Supports multiple business models • User-friendly interface • Access to innovation

According to Table 1 and the report of Hari (2025), a comparison of leading AI-driven ERP solutions, including Oracle Cloud, SAP S/4 HANA, Acumatica, Microsoft Dynamics 365, Oracle NetSuite, and Infor, reveals that while these platforms provide powerful AI capabilities, their effectiveness varies based on cost, customization flexibility, and implementation complexity.

Oracle Cloud excels in machine learning and NLP applications but poses financial constraints for SMEs. SAP S/4 HANA is strong in predictive analytics but has high implementation costs. Acumatica supports automation but has limited community

support. Microsoft Dynamics 365 offers advanced anomaly detection but features a complex user interface. Oracle NetSuite specializes in big data analytics but presents cost-benefit concerns for mid-sized enterprises. Infor is effective in cost analysis but has scalability limitations for large enterprises.

Overall, AI-driven ERP systems enable businesses to improve operational efficiency and gain a competitive edge. However, their successful adoption depends on company size, industry-specific needs, and financial capabilities. While AI enhances ERP functionalities, businesses must evaluate software suitability based on strategic goals and resource availability (Hari, 2025).

5 Discussion

This study has explored the impact of AI-based ERP systems on business processes and their role in digital transformation. The integration of AI technologies into ERP systems provides significant advantages in areas such as efficiency improvement, cost optimization, process automation, and the enhancement of strategic decision support mechanisms. The effects of AI usage are particularly evident in ERP sub-modules such as customer service, finance, production and sales. The successful implementation of these technologies requires robust technical infrastructure, trained personnel, and appropriate management policies. Businesses must consider factors such as cost, time, and organizational change management during the transition to these technologies. For small and medium-sized enterprises (SMEs), these considerations are often particularly challenging given their constrained budgets and limited specialized personnel. Many leading AI-driven ERP platforms entail high implementation and maintenance costs, which can be prohibitive for smaller firms (Hari, 2025). Furthermore, SMEs may lack in-house expertise to manage complex AI integrations, and they have fewer resources to absorb the risks and disruptions associated with major technological changes. These obstacles can slow down SME adoption of AI-supported ERP systems despite the clear potential benefits. Therefore, developing cost-effective and scalable AI-ERP solutions tailored to the needs of SMEs is critical to accelerating their digital transformation processes. The findings of this study offer valuable insights by highlighting practical approaches that smaller enterprises can employ to harness AI within their ERP environments. By identifying key areas—such as using predictive analytics for demand forecasting or deploying process automation for routine tasks—where AI

integration yields immediate efficiency gains, this research provides a roadmap for SMEs to prioritize investments that deliver high impact. In doing so, even resource-constrained businesses can leverage AI-driven ERP capabilities to streamline their operations and enhance their competitiveness. In addition to the SME-focused insights, there are broader considerations for the successful integration of AI and ERP systems. Investigating the effects of AI algorithms on data security, regulatory compliance, and regional differences remains a critical step toward ensuring the widespread applicability of AI–ERP solutions. For example, assessing the impact of regulations such as the European Union's General Data Protection Regulation (GDPR) on the functionality of AI algorithms is crucial to guarantee that AI-empowered ERP systems remain effective and compliant across different jurisdictions. In conclusion, AI-supported ERP systems play a strategic role in optimizing business processes and providing a competitive advantage for businesses of all sizes.

6 Conclusions

AI-supported ERP solutions provide significant advantages in areas such as selecting the right resources in supply chain management, optimizing procurement processes, and rapidly resolving related issues. The integration of AI technologies such as machine learning and natural language processing (NLP) into ERP systems enhances customer services, analyzes consumer behavior, generates feedback, and supports sales forecasting, delivering substantial benefits. Additionally, AI-supported systems that provide real-time information enable businesses to quickly adapt to changing market conditions. This study has examined the organizational benefits of integrating AI into ERP systems in detail, aiming to contribute to literature. The research results indicate that AI-supported ERP systems hold great potential in areas such as error-free data management, simultaneous integration of all departments, and sales and demand forecasting. Future studies could conduct a comparative analysis of ERP solutions in terms of AI usage, and they can also conduct case analyses on the applications of AI-supported ERP systems across different industries.

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The Impact of Financial Intermediation on Economic Growth: An Econometric Analysis for the Western Balkan Countries

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This paper aims to study the impact of financial intermediation on the economic growth of the Western Balkan countries. For the implementation of this paper, we will use secondary data. For data collection, we will focus on the reports of the World Bank, IMF and Eurostat. In terms of literature review, we will use materials provided by various scientific works focused on the field of financial economics, conference materials, various books, etc. The analyzed period will be 10 years. Based on the empirical results obtained from this paper, we can say that credit and inflation have not affected financial intermediation on the economic growth of the Western Balkan countries during the years 2013 - 2022. While the interest rate and deposits have had a positive impact. Through the results obtained, we say that the results of this study will serve as good scientific and empirical evidence for future studies to be conducted in the field of financial economics. This paper presents real and consistent results regarding the relevant conclusions. The analyzed period (2013-2022) is a compelling period for drawing competent conclusions and recommendations.

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1 Introduction

In this research, we will analyze how financial intermediation affects economic growth in the Western Balkan countries. We will focus on the importance of financial institutions, capital markets, and financial market infrastructure in promoting investment, developing important economic sectors, and improving sustainable conditions and inclusive economic growth in this region.This study aims to provide an in-depth analysis of the complex links between financial intermediation and economic development in the Western Balkans, highlighting the challenges and opportunities for the future of these countries in the context of regional integration and the global impact of financial markets.The role of financial intermediation in economic growth has been widely recognized in many different research studies. The main engines of economic growth, capital and total factor productivity, can be stimulated and influenced by finance. Financial intermediaries favor savings and reduce the transaction costs associated with capital accumulation. By allocating funds to the most productive initiatives and keeping an economic eye on them, financial intermediaries play a critical role in increasing total factor productivity (Yusifzada & Mammadova, 2015).

The paper is divided into four sections. The first part includes the literature review, the second part includes the scientific methodology and the specification of the econometric model. The third part includes the statistical analysis and findings of the study, while the last part includes the conclusions and discussions of this study.

2 Literature review and meta-analysis

Financial intermediation has been the subject of study for many years. It has been said many times that financial intermediation plays a very important role in the economic development of a country because it is crucial in channeling funds to productive users, promoting economic development and improving opportunities for income distribution and poverty reduction. Credit is a large amount of money that a bank gives to a citizen, or society, etc., at their request, on condition that it is returned in installments within a certain time (Hadëri, 2006).

A financial intermediary acts as a middleman between two parties to a financial transaction, such as a commercial bank, an investment bank, a mutual fund, or a pension fund. Financial intermediaries provide a number of benefits to the consumer, including security, liquidity, and economies of scale inherent in banking and asset management. While in certain areas, such as investing, advances in technology threaten to eliminate the financial intermediary (Chen, 2020). Author (Pagano, 1993) explains three channels through which financial development can affect economic performance. First, financial intermediaries improve the efficiency of investment. Second, efficient financial systems reduce transaction costs and increase savings as a result. Third, financial sector development can increase or decrease savings. Much of the literature on economics has addressed how financial institutions can influence the acceleration of economic expansion. Several years earlier, (Schumpeter, 1934) used the function of the banking industry as an intermediary to identify how it finances technological advances. Schumpeter explained how this goal could be achieved by identifying and financing business owners who have innovative concepts and creative production techniques to efficiently distribute savings. Levine (1997) and Schumpeter (1934) argued that economic progress resulted from the interaction between financial and real advances. The importance of financial markets and financial intermediaries for economic growth was emphasized by Schumpeter. This view was supported by (Hicks, 1969) who argued that financial resources were necessary for developing countries to industrialize.

Table 1: Meta-analysis of research

Author	Year	Title	Methodology	Finding
(Azege, 2004)	1970-2003	The Impact of Financial Intermediation on Economic Growth: An Analysis for Nigeria	Correlation analysis	Based on data, approximately 30% of Nigeria's GDP growth over the years has come from the banking sector's credit allocation to the economy, according to data analysis in this research.
(Seven & Yetkiner, 2016)	1991-2011	Financial intermediation and economic growth: Does income matter?	Panel data	The evidence suggests that financial development positively impacts economic growth in low- and middle-income countries. In high-income countries, the effect is detrimental.

Author	Year	Title	Methodology	Finding
(Ibrahim, 2012)	1970-2010	Financial Intermediation and Economic Growth in Nigeria	Time series Data	The comprehensive results of the study show that financial intermediation contributes to economic growth in Nigeria. This study shows that the years 2004 to 2007 were considered anomalous during the last ten years of the study. During this period, credit to the private sector grew at high rates, while the capacity utilization rate grew at the slowest average annual growth rate.
(Atindéhou., Jean Pierre, & Edoh Kossi, 2005)	1961-1997	Financial intermediation and economic growth: evidence from West Africa	VAR analysis	Based on the results, we see that for all financial factors considered, there is no causal relationship between economic development and any of the three countries analyzed. Mauritania shows some elasticity because economic growth seems to be affected by all financial factors.
(Orenuga & Oyedokun, 2022)	1970-1980	Financial intermediation and economic growth in developing countries	Panel data	Both channels of financial intermediation are important in developing countries; financial depth, which is the ratio of financial aggregates to GDP, only stimulates economic growth in low-income developing countries; in high-income countries it has no effect.
(Hao, 2006)	1985-1999	The development of financial intermediation and economic growth: The Chinese experience	The GMM model	According to econometric findings, the development of financial intermediation in China has two impacts on the country's economic growth: first, it replaces state budget allocations with credit and second, it mobilizes household savings. However, because credit is distributed inefficiently through financial intermediaries, credit growth does not stimulate growth.
(Sebuhuzu & Harold, 2017)	1996-2010	Financial Intermediation and Economic Growth:	Panel data	The study finds a cointegrated relationship between financial intermediation and economic growth in Rwanda, with private sector credit and liquidity

Author	Year	Title	Methodology	Finding
		Evidence from Rwanda		shocks driving output fluctuations. Strengthening the financial sector can boost economic growth.
(Emmanue & Odum, 2019)	1986-2017	The Effect of Financial Intermediation on the Economic Development of Nigeria	Autoregressive Distributed Lag (ARDL) technique.	From the research we say that lending to the private sector does not stimulate economic growth. The reason for this may be interest rates that can negatively affect economic growth. Therefore, it is suggested to reduce interest rates to increase the performance of the productive sectors of the economy.

Source: Data analyzed by authors (2025)

3 Methodology

The purpose of this study is to analyze the impact of financial intermediation on economic growth in the countries of the Western Balkans. To carry out the research, it will use secondary data provided by reliable sources from the World Bank, the International Monetary Fund and others. Also, in the literature review part, we will focus on the works of different authors on the determinants of financial development, together with relevant books by experts in the fields of finance, economics and management. Also, we will focus on various international conferences, numerous reports and safe resources from the Internet. The study will use panel data covering a 10-year period (2013-2022). For data processing we will use the STATA software program. The importance of the paper lies in its aim to provide real and consistent results that can shed light on financial intermediation and economic growth. The data will be processed in the STATA program and to prove the validity of the hypotheses of this study, we will apply the following statistical tests: descriptive statistics, linear regression, random effect, fixed effect, Hausman - Taylor regression, GMM, Arellano Bond Valuation Model, Generalized Valuation Equations (GEE Model).

The research questions of this research are:

1. How does credit, deposits, inflation and interest rate affect the GDP of Western Balkan countries?

2. How does credit affect the economic growth of the countries of the Western Balkans?
3. How does the interest rate affect investments and the economic development of the countries of the Western Balkans?

The hypotheses of this paper are constructed in this way:

H0: Financial intermediation does not affect economic growth in Western Balkan countries.
H1: Financial intermediation affects economic growth in Western Balkan countries.

Table 2: Description of the variables included in the econometric models

Variables	Description of variables	Data source
Dependent variable (Y)	Gross Domestic Product (% GDP)	Annual Reports of the BankWorld (2013-2022)
Independent variable (X1)	Domestic credit to the private sector (% of GDP) (C)	Annual Reports of the BankWorld (2013-2022)
Independent variable (X2)	Inflation, consumer prices (annual %) (I)	Annual Reports of the BankWorld (2013-2022)
Independent variable (X3)	Real Interest rate (annual %) (IR)	Annual Reports of the BankWorld (2013-2022)
Independent variable (X4)	Bank deposits to GDP (annual %) (D)	Annual Reports of the BankWorld (2013-2022)

Source: Data analyzed by the authors (2025)

The econometric model that will be used in this study is specified as follows:

$$GDP = \beta_0 + \beta_1 C + \beta_2 I + + \beta_3 IR + \beta_4 D + \gamma it$$

4 Results

In the chapter, the results will be presented through econometric analysis, where in this part the hypotheses presented in the research will be tested and we will try to get answers to the research questions presented earlier. Initially, descriptive statistics, linear regression, fixed effect model, random effect model, Hausman Taylor Estimation, GEE Model and GMM Model will be analyzed in this part. All these results will be extracted through the STATA program.In the following table, descriptive statistics will be presented for the variables included in the research,

where the part of observations, the average, the standard deviation, the minimum and the maximum of the variables will be analyzed.

Table 3: Descriptive statistics for the variables included in the econometric model

Variables	Obs.	Mean	Std.Deviation	Minimum	Maximum
GDP	70	2.957143	4.192905	-15.3	13.8
Loans	70	48.53857	8.591693	33	68.3
Inflation	70	2.095714	3.249278	-1.1	14.2
Deposits	65	4.002646	.171474	3.634951	4.347694
Interestrate	43	1.399159	.7407248	-1.203973	2.433613

Source: Author's calculations in Stata (2025)

Based on the data obtained from descriptive statistics, we can observe that the sample of our work is of 70 observations, as for the average, we see that the variable with the highest average is credit. If we analyze the part of the standard deviation, we can notice that we have the highest value of the standard deviation in the credit variable as well, in the part of the minimum value is the inflation variable, and as for the maximum value, again the loan has the highest value.

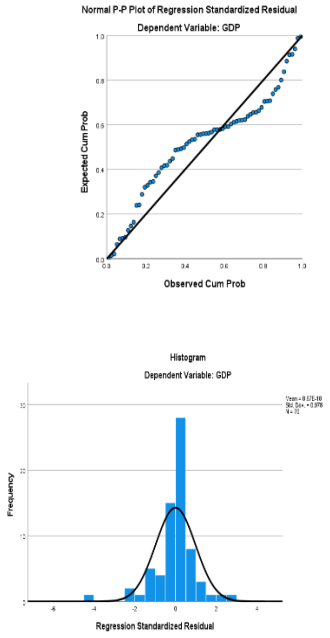

Figure 2: Graphic representation of the histogram
Source: Authors' calculations in Stata (2025)

Based on the graphical representation of the histogram, we see that between the dependent variable of GDP and the independent variable there is a normal distribution of these variables included in the analysis.

$$GDP = \beta_0 48.06739 + \beta_1 -.0987749 + \beta_2 .8647457 + \beta_3 -1.560745 + \beta_4 9.810035 + \gamma it$$

Table 4: Econometric results and empirical findings of the study

Variablat	Linear Regression	Random Effects – GLS Regression	Fixed – Effects Regression	Hausman – Taylor Regression	GEE Model	GMM Model
GDP	-	-	-	-	-	-
Loans	-.0987749 (0.144)	-.0987749 (0.136)	-.6989152 (0.004)**	-.4724482 (0.009)**	-.0614614 (0.077)*	-1.045368 (0.000)***
Inflation	.8647457 (0.152)	.8647457 (0.143)	1.293724 (0.039)**	1.258286 (0.035)**	.1209602 (0.784)	1.110983 (0.057)**
Interest rate	-1.560745 (0.071)**	-1.560745 (0.063)**	-1.370628 (0.156)	-1.505059 (0.101)	-.5019236 (0.478)	-.5130925 (0.498)
Depozits	-9.810035 (0.027)**	9.810035 (0.022)**	-12.25491 (0.227)	-14.15431 (0.128)	-3.713612 (0.050)**	-13.63079 (0.149)
Const.	48.06739 (0.009)**	48.06739 (0.006)**	86.38403 (0.030)**	86.71609 (0.022)**	20.92214 (0.020)**	30.12865 (0.002)**

Source: Authors' calculations in Stata (2025)

Explanation: P-values are shown in brackets: *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level and * indicates 10% statistical significance.

Based on the econometric results in the table above, we can conclude that some of the independent variables are significant at the 1%, 5% and 10% levels. For interpretation purposes we will base on the Random Effects GLS model, where in this regression the results are better.

β0 - If all other factors are constant, then GDP will be 48.06739 units.

β1 – If private sector credit increases by one unit holding all other variables constant then GDP will decrease by -.0987749 units. This statement is not correct as it is not within the 5% confidence interval, because (p-value = 0.136>0.05). If we analyze it from an economic aspect, we can say that the increase in credit for the private sector can stimulate investment and consumption, allowing businesses to expand and improve their production capacities, as well as consumers to increase their spending

on goods and services. This increase in investment and consumption can lead to increased economic activity and job creation, contributing to overall GDP growth.

β2 – If inflation increases by one unit, holding all other variables constant, then GDP will increase by 0.8647457 units. This statement is not correct as it is not within the 5% confidence interval, because (p-value = 0.143>0.05). If inflation increases, GDP can be negatively affected. Increased inflation leads to higher prices for goods and services, which can reduce consumer purchasing power and reduce consumption. In addition, increased costs for businesses can reduce profits and reduce new investment. This combination of reduced consumption and investment can slow economic growth and lead to a decrease in GDP.

β3 – If the interest rate increases by one unit, holding all other variables constant, then GDP will decrease by -1.560745 units. This statement is correct because the significance value is within the 10% confidence interval, because (p-value = 0.063<0.10). Increasing interest rates makes it more expensive for consumers and businesses to obtain credit, reducing consumer spending and business investment. This reduces aggregate demand in the economy, slowing economic activity. In general, increasing interest rates tends to slow economic growth and reduce GDP.

β4 - If deposits increase by one unit, holding all other variables constant, then GDP will increase by 9.810035 units. This statement is correct since the significance value is within the 5% confidence interval, because (p-value = 0.022<0.05). An increase in bank deposits improves the liquidity of financial institutions, enabling them to provide more credit to businesses and consumers. An increase in credit can encourage businesses to invest in expanding production capacities and increasing individual consumption, leading to an increase in economic activity.

5 Conclusions and discussion

The topic of the impact of financial intermediation on the economic growth of the Western Balkan countries is important for understanding how to improve the financial infrastructure and stimulate economic development in the region.

From the analyses conducted and the results obtained, we can conclude that financial intermediation has a positive impact on economic growth and that the base hypothesis (H1) in this case is accepted and H0 is rejected. From the tests conducted through the STATA program, we noticed that some of the variables were related to each other and some of them were not. Credit and inflation were two of the variables that did not have much impact on economic growth. This is as a result of various economic factors. Credit for the private sector has not had much impact because those loans that businesses receive do not directly affect economic growth because most businesses receive those loans to justify to the state that they are in credit and should not burden us with many obligations. While the interest rate and the deposit rate had a positive impact on the economic growth of the Western Balkan countries. Overall, the results were acceptable for the period analyzed, given that there was also a lack of data in some countries.In the Western Balkan countries, financial intermediation has played an important role in facilitating access to financial resources for businesses and individuals. Intermediation has improved access to credit and stimulated economic activity by supporting investment and consumption. However, there are major challenges that hinder the full potential of financial intermediation in these countries, such as the lack of financial market infrastructure, low property registration, and weak financial management standards in financial institutions. Investments in the development of financial infrastructure and increased transparency in financial systems will help address these challenges and increase the impact of financial intermediation on the long-term economic growth of these countries.

During this research, we also encountered some limitations such as the lack of data for some countries which affected the reduction of the sample of the work and the lack of research of this nature for the Balkan countries. But we conclude that the results of our work are original and reliable,through the obtained results, we say that the results of this study will serve as good scientific and empirical evidence for future studies that will be carried out in the field of financial economics. The results of this study will serve as practical evidence for the governments of different countries of the world regarding the part of financial development and financial intermediation of a country, how to design strategic macroeconomic policies that will positively affect the financial development of economies. of the countries of the Western Balkans.

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Sustainability and Complementarity of Agriculture and Rural Areas in the EU

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The main tasks of agriculture are undoubtedly food production and fulfilling its non-productive functions. This complementarity is realised particularly in the rural area. The aim of this paper is to evaluate the economic performance of selected EU countries in terms of labour productivity in the rural space and agrarian space, first from a macroeconomic perspective. From a microeconomic perspective, the analysis is carried out for the average agricultural enterprises of the EU countries. The evaluation is carried out for the EU Member States from 2004 to 2022 using the Eurostat and FADN databases. A certain limitation was the Eurostat database, which does not contain complete data for all countries and years. Labour productivity was analysed using cluster analysis. It was found that there are significant differences in labour productivity of the average farm between the original EU member states and the new accession countries since 2004. The exclusion of subsidies caused a 15% decrease in labour productivity. Moreover, the findings are substantially influenced by the price level in each of the countries studied, as well as the degree of urbanisation and the share of Rural Areas in these countries.

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1 Introduction

The paper connects relatively autonomous considerations of agriculture as a sector of the national economy that influences the performance of the economy and rural simplicity, without which the various functions of agriculture cannot be realized. Agriculture and the countryside are seen as complements that cannot be viewed separately if sustainability aspects are to be fulfilled. Sustainability and the complementarity of agriculture and rural areas in the EU countries are two important interlinked concepts that are part of the European Union's Common Agricultural Policy (CAP).

Agriculture is a key part of the rural economy and society, but rural areas also include other aspects such as services, forestry or local business. It is, therefore, a matter of ensuring that economic policy supports not only food production and agricultural activities but also the development of other rural activities that can help to diversify the rural economy and improve living conditions in these areas.

2 Theoretical Background / Literature Review

For more than two decades, the relationship between agriculture and the countryside has been intensively studied. Cairol et al. (2009). This relationship can be examined in a wide range of aspects, including, among others, social, economic and environmental. Kasimis (2010), Kalantaryan et al. (2021) not only in the context of economic and social have analysed the migration process and integration in the context of rural and agriculture. Kusio et al. (2022) analysed the positive functioning of rural communities in relation to support by way of social and structural policy instruments and measures, using the example of five European rural regions.

The links between economic and environmental through the analysis of the relationship between multifunctionality and agricultural sustainability were explored by Casadevall (2016) using Eurobarometer reports. The role of environmental aspects in rural development was highlighted by Take Barbier (2025). Papadopoulos (2015) explored the promotion of the functioning of rural areas and agriculture through CAP instruments and measures. According to some studies, the public, consumers and researchers (Hart and Bas-Defossez, 2018; Lakner and Pe'er, 2018; Recanati et al., 2019) have long criticised CAP and called for a paradigm shift

towards more environmentally, socially and economically sustainable policies (Rac, Erjavec and Erjavec, 2015). Similarly, with a focus on food security, Volyk et al. (2023) examined farm competitiveness.

The increasing role of digitalisation and its impact on rural life, based on the use of rural development tools and measures, has been explored by Ferrari et al. (2022), Preston et al. (2007), Koutridi, E., & Christopoulou, O. (2023), Ma et al. (2023). A critical perspective on the use of some of these tools is offered by Prusa et al. (2022), with an emphasis on the possibilities of increasing rural resilience by harnessing its endogenous potential.

The Common Agricultural Policy (CAP) is the most important common policy of the European Union and is one of the few areas funded mainly by the European Union. Although the share of the CAP in the EU budget has decreased from 66% in 1980 to 35% in 2020 (Lillemets, Fertő and Viira, 2022), it still constitutes a significant part of total EU spending. It can, therefore, be expected to substantially impact the economic, environmental, and social aspects of agriculture and life in rural areas.

According to the most recent change to the CAP, member states are supposed to have increased subsidiarity in the planning and implementation of the CAP. Each Member State has drawn up a CAP strategic plan, which includes interventions for Pillar I (direct payments) and Pillar II (rural development). The preparation of the plan is based on quantitative and qualitative current information that will provide a thorough analysis of the current situation in the country, actively involve all related economic and social partners, and will be connected to a set of common economic and biophysical indicators defined in the regulation (Kremmydas and Tsiboukas, 2022).

3 Methodology

The paper has two aims. From a macroeconomic perspective, taking into account the degree of urbanisation, the aim is to assess the economic performance of selected EU countries in terms of labour productivity in rural areas and to provide a more detailed view on labour productivity in sector Agriculture, forestry and fishing. From a microeconomic perspective, the aim is to assess the economic situation of the EU

countries in terms of labour productivity of average farms and the impact of CAP on the development trends in the agricultural sector as one of the foundations for the sustainability of the rural area. The examination of the broader socio-economic framework was carried out in relation to the population of rural households in each EU Member State. Furthermore, the examination focused on the analysis of a purely economic category, which is labour productivity. This was first examined as the level of gross domestic product generated in the rural area per 1 employed person in the rural area (LP_R) and then, in more detail, this labour productivity was examined at the level of value added generated in the agricultural sector in the rural area per 1 employed person in the rural agricultural sector (LP_RA).

The data were taken from the Eurostat database. Due to the lack of data on the share of RH in 2005 in the Netherlands, Romania and in 2020 in Sweden, these data were replaced by the closest published data. In addition, Cyprus, Malta and Luxembourg were excluded from the analysis due to missing data. The analyses examined were carried out using Statistica software.

Labour productivity (LP_R) in rural regions was calculated as a share of GDP in million EUR (GDP) on thousand employed persons in rural areas (EPR).

$$LP\_R = {}^{\mathrm{GDP}}/_{\mathrm{EPR}}$$

The other indicator is labour productivity in rural areas (LP_RA) in the sectors of Agriculture, forestry and fishing. It was calculated as Gross value added in the sector of Agriculture, forestry, and fishing at basic prices (GVA) on thousand employed persons in Agriculture, forestry and fishing (EPRA) predominantly in rural areas.

$$LP\_RA = {}^{\mathrm{GVA}}/_{\mathrm{EPRA}}$$

Tables 1 and 2 below show descriptive statistics for variables LP_R and LP_RA in the years 2005 and 2020.

Table 1: Descriptive statistics for variable LP_R

Variable	Descriptive Statistics LP_R				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
LP_R_2005	24	36,41026	5,95765	68,7418	22,61550
LP_R_2020	24	53,05480	14,54034	138,2938	30,53757

Source: Eurostat (2025), authors calculation.

Table 2: Descriptive statistics for variable LP_RA

Variable	Descriptive Statistics (RH_LP_RA)				
	Valid N	Mean	Minimum	Maximum	Std.Dev.
LP_RA_2005	24	17,07923	2,091008	35,30056	11,88636
LP_RA_2020	24	32,54304	4,165072	84,73684	22,67565

Source: Eurostat (2025), authors calculation.

For the analysis of the economic results of agricultural holdings, data from the public database The Farm Accountancy Data Network (FADN) in the EU in the years 2014-2022 (2025, European Commission) was chosen. The standard output of FADN is a set of indicators (SE) - results of agricultural holdings officially published for individual types of holdings within the FADN system. The purpose of the EU methodology is to allow the evaluation and comparison of the economic results of agricultural holdings in individual EU countries according to a uniform methodology, which is not influenced by differences in tax accounting records. The following indicators were selected as the indicators to be assessed: Total labour input (AWU = annual labour unit indicating the amount of labour input, which is derived from the number of hours worked, 2000 hours = 1 AWU, SE 010); Paid labour input (AWU - SE 020); Total Outputs (TO, € - SE 131); Total subsidies - excluding on investments (TS, € - SE 605); Total Utilised Agricultural Area (ha - SE 025):

$$LP = {}^{(\mathrm{TO}+\mathrm{TS})}/_{\mathrm{SE}}$$

The relationship of the analysed indicators with the CAP subsidy policy is demonstrated by calculating labour productivity in two variants, including and without subsidies. Based on the data, processed by cluster analysis, a multi-variable statistical method dividing the large groups of observation into smaller and more homogeneous groups could be carried out. The clustering process can be roughly divided into three categories – hierarchical, non-hierarchical and a two-stage category. Ward´s method was used in this article (Rencher (2002).

4 Results

The average increased in both years, but much more dynamism was recorded in the LP_RA indicator, where there was almost a 100% increase.

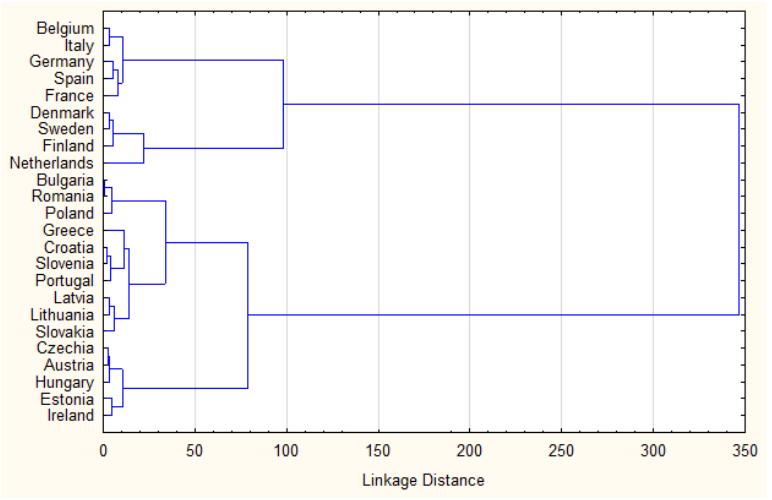

Figure 1: cluster analysis – variable LP_R (2005 and 2020)
Source: Eurostat (2025), authors calculation.

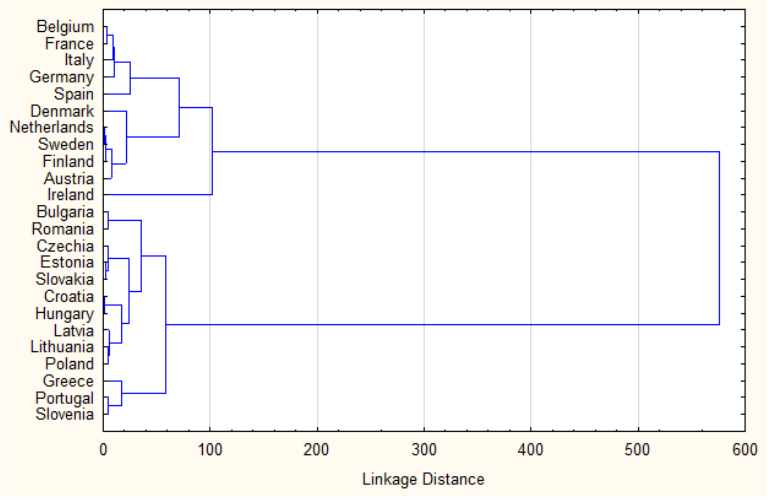

Figure 2: Cluster analysis – variable LP_RA (2005 and 2020)
Source: Eurostat (2025), authors calculation.

Figures Number 1 and 2 show the results of a cluster analysis examining labour productivity in rural areas across 24 European countries. Two separate analyses are shown, likely representing data from different years or using different productivity metrics. The difference in the results of the analyses probably reflects the fact that other sectors that are more productive contribute to higher productivity in (PL_R) rural areas. There is a special structure of economic activities in rural areas, where agriculture is one of the most significantly represented sectors. Other sectors are not as strongly dependent on natural and climatic conditions.

The analyses reveal substantial heterogeneity in agricultural labour productivity across European countries. The differing clustering patterns between the two analyses underscore the importance of carefully defining and measuring productivity. The data likely reflects variations in factors such as technological advancement, agricultural practices, land quality, and government policies across the countries.

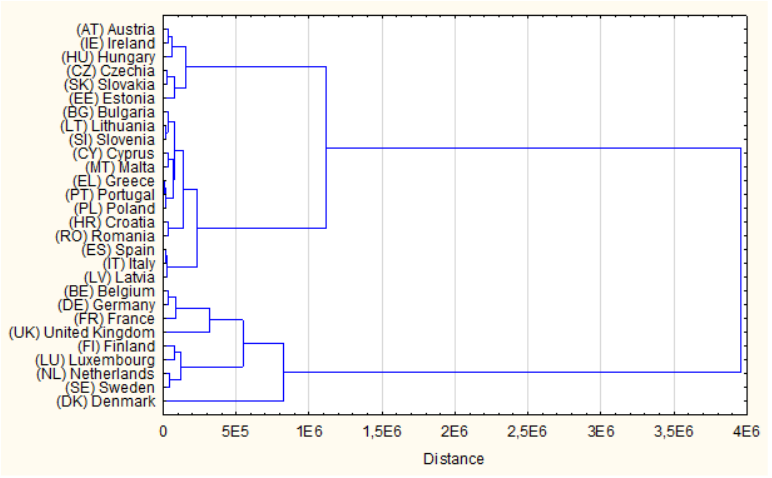

Figure 3: Cluster analysis – variable LP EU (2004 - 2022)
Source: FADN (2025), authors calculation.

The expected fact is probably indicated by two main clusters (Figure Number 3), which reflect the division of EU countries according to accession to the EU – i.e., the original Member States and the newly acceding states since 2004. For further evaluation, 7 clusters were chosen, which best represent the groups of countries with

similar development of the monitored indicators and are evaluated from the most productive countries. Denmark was evaluated as a stand-alone cluster, which achieves the highest average labour productivity of about 255 thousand € in the EU. Its number of employees measured by AWU is slightly above the EU's of 1,9, but its average revenues are the second highest in the entire EU, at 491 thousand €, which have been growing enormously in the last 5 years or so. Denmark is the largest exporter of pork products in the EU. In addition, there is also important cattle and poultry breeding, as well as sea fishing. At the same time, cereals (wheat), potatoes, and sugar beet are grown here.

The second cluster consists of Sweden, the Netherlands, Luxembourg, and Finland, with an average value of labour productivity of about 155 thousand €. When evaluating the sub-indicators, it is worth emphasizing that the Netherlands achieves the most total yields here, almost twice as much as the other countries in the cluster, which achieves the highest AWU, which is again about twice as high. The reason is that the Netherlands uses its land resources very intensively and, at the same time, has favourable climatic conditions that guarantee high production. The average growth rate of this group is about 5%. In the third cluster, the United Kingdom, France, Germany, and Belgium can be traced – the value of labour productivity per average enterprise is about 117 thousand € with a growth rate of 3,5%. These countries have very balanced yield values and AWU (slightly over 2). A typical feature of the fourth cluster for Czechia and Slovakia is a significantly above-average production (Slovakia 803 thousand €, which is the highest in the EU, Czechia 442 thousand €) accompanied by a high AWU value (Czechia – 6,3 and Slovakia 13,5). The high production volume is due to the historical development in these countries and the preservation of the type of farms with the highest area in the EU. When converted to labour productivity, Estonia is also part of the cluster; this cluster has about 1,5 times the EU average – i.e., 71 thousand € and achieves the highest growth rate of 9,5%.

The fifth cluster is Hungary, Austria, and Ireland, which have relatively balanced values in terms of both revenues and AWU. The average productivity here is 60 thousand €, with a growth rate of 4,8%. With an average labour productivity of about 37 thousand € and a growth rate of 5,8%, Latvia, Italy, and Spain are in the sixth cluster. Latvia has the highest yields here (about 1,5 times higher than Italy). The last cluster, which includes the most significant number of countries, is characterized by

a mix of newly joined countries to the EU (Romania, Croatia, Poland, Slovenia, Lithuania, and Bulgaria) and original countries that have a specific position due to their natural conditions, these are island states such as Malta, Cyprus, Greece, and Portugal also fall into this group. Agricultural enterprises have a labour productivity of about 22 thousand € but a higher growth rate of about 7%. A common feature is a lower AWU value below 2 (except for Bulgaria, with 2.7 AWU, which has the highest yields).

From the point of view of AWU, it is appropriate to add an important fact typical for the area of agricultural enterprises or farms – namely, the share of paid labour. It is about 27% in the EU and is related to the historical development of the countries in question and the overall relationship to rural areas and regional policies. The highest share of paid power is held by large companies in Slovakia (92%) and in Czechia (78%). Furthermore, the share decreases by around 55%, such as Hungary, Estonia, and Denmark. On the other hand, the lowest share of paid AWU, with 10%, is in Malta, Austria, or Ireland, and the lowest of the entire EU is employed in Slovenia, with about 4%.

5 Discussion

In terms of labour productivity, both in the rural area as a whole and in the agricultural sector in the rural area, there has been an increase in the period under review. The dynamics of increase was more moderate in rural areas, irrespective of sectoral focus. Significant productivity increases were recorded in the agricultural sector, with the initial level of labour productivity in rural areas (53,1 thousand €) almost double that of agricultural productivity in rural areas (32,5 thousand €). It can thus be concluded that there has been a narrowing of the gap in the level of labour productivity in rural areas. Productivity is reflected in the income situation of the rural population (Shucksmith et al., 1994, Davis et al., 1997, Karlsson et al., 2005, Chmieliński and Chmielewska, 2015, Bernard, 2019).

Thus, examining the dynamics of agricultural labour productivity is crucial to understanding the development and transformation of agriculture within a country or region (Balezentis et al., 2021). Based on the 2014-2022 time series in EU countries, an average labour productivity of 49.5 thousand € was found per average farm with a growth rate of about 4%. In determining the labour productivity

indicator in relation to the subsidy policy, productivity was adjusted for operating subsidies, which are accounted for as part of revenues. The reduction in revenues, therefore also led to a lower productivity of EUR 41,8 thousand €. The impact of the subsidy policy was not reflected in the different cluster structures.

Many studies have addressed the issues of subsidy efficiency and overall profitability. To date, there is no common consensus on whether the economic impact of subsidies is positive or negative, mainly due to the incomparable approaches used by researchers in empirical research (Bernini & Galli, 2024). Cost-effectiveness is evaluated in a similar way as profitability (e.g. Svoboda, 2020). The impact of piecemeal approaches to rural and agricultural support is reflected in the quality of life of rural residents (Shucksmith et al., 2009; Baldwin et al., 2023).

6 Conclusions

Rural areas and agriculture are complementary because they form a mutually supportive and interconnected system. This relationship is important in the broader social, economic and environmental context. Agriculture has traditionally been a major producer of agricultural commodities, and for rural communities, agricultural production is often a key economic pillar that provides jobs and supports local businesses. At the same time, agriculture can contribute to maintaining the landscape by protecting it from erosion, promoting biodiversity, looking after water resources, etc.

Labour productivity on the average EU farm has risen by 50% in almost 20 years of monitoring to 75,000. The main differences are seen between the original EU member states and the newly acceded countries since 2004. The link to the Common Agricultural Policy in terms of subsidies showed a 15% reduction in productivity, but the distribution of countries using cluster analysis remained the same. The findings are substantially influenced by the price level in the only countries examined. Similarly, the observed differences are influenced by the degree of urbanisation and the share of Rural area in these countries.

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Environmental, Social, and Governance (ESG) Performance and Economic Growth: An Econometric Analysis for Central European Countries

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This study analyzes the impact of environmental, social, and governance (ESG) performance on economic growth in Central European countries. Using an econometric approach, the study assesses ESG indicators' contribution to economic development and examines whether these factors drive sustainable growth. A scientific methodology based on secondary data from the World Bank's annual reports was applied. Several econometric models, including multiple linear regression, random effects, fixed effects, Hausman-Taylor regression, GMM, and GEE models, were used. The results show a strong relationship between ESG performance and economic growth. Governance effectiveness and corruption control positively impact GDP growth, while increasing CO2 emissions negatively affect it. Similarly, investments in education and health contribute to long-term growth, emphasizing the importance of sustainable development policies. This research presents reliable results supporting conclusions and recommendations.

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1 Introduction

This research paper examines the impact of environmental, social, and governance (ESG) performance on the economic growth of Central European countries during the period 2014–2023. In contemporary discourse, sustainable development emphasizes the necessity of addressing both social and environmental priorities to safeguard the long-term welfare of all participants within the economic system. ESG indicators, encompassing non-financial metrics, play a pivotal role in this context. These indicators cover environmental dimensions (such as resource management, greenhouse gas emissions, and sustainable energy use), social aspects (including workforce diversity, inclusivity, and ethical supply chain practices), and governance-related factors (such as leadership autonomy and balanced board representation). Increasingly, these dimensions are recognized by economic actors as fundamental drivers of sustainable and resilient growth (Boffo & Patalano, 2020). Effectively managing ESG risks through responsible and forward-looking business strategies can significantly contribute to enhanced economic development. In this regard, businesses are increasingly required to realign their strategic objectives and transform their organizational cultures to foster sustainable progress and ensure the long-term welfare of employees, consumers, and other key stakeholders (Jolevska, et al., 2024). Over the past decades, ESG considerations have evolved into some of the most impactful and transformative forces shaping corporate practices and broader economic landscapes (Li, et al., 2021). Existing literature presents mixed findings regarding the relationship between ESG performance and economic growth. Broadly, three perspectives can be identified: (1) a mutual and reinforcing relationship between economic growth and ESG performance; (2) a partial or conditional relationship depending on specific factors; and (3) no significant relationship observed between the two dimensions. Despite growing academic interest, the exploration of how national-level ESG metrics interact with economic performance remains a relatively nascent field. As such, further research is essential to provide deeper and more comprehensive insights into this evolving relationship.

2 Literature review

In 2004, ESG was created as a tool to help investors identify and communicate long-term risks that have a significant impact (Hearn, et al., 2022). The assessment of environmental, social and governance (ESG) factors has gained increasing

importance, becoming increasingly present in academic literature and business practices (Clément, et al., 2023). ESG can be described as a broader classification that defines the non-financial objectives of an organization (Krishnamoorthy, 2021). The performance of ESG factors has a significant impact on the efficiency of markets, the development of new investments and the use of innovative technologies, bringing significant benefits to overall growth and development. Implementing an ESG framework is essential for building a sustainable business model (Sibarani, 2023).

Some scholars suggest that economic growth can serve as a catalyst for improving ESG performance, claiming that accelerated economic expansion can lead to significant improvements in ESG indicators. They argue that rapid growth strengthens a country's ability to sustain high levels of investment, which helps advance technology and encourages innovation. Sustainable growth requires investments that are socially responsible, which deserve in-depth assessment (Syed, 2017). Ambitions for sustainable development are closely linked to improving an organization's competitiveness and innovative capacity (Starks, 2021).

Revelli and Viviani (2015) argue that sustainable finance, including ESG investments, can contribute to improving performance by integrating business practices with investor values and societal expectations. According to Shahrour et al. (2023), ESG initiatives play an important role in reducing risks and promoting sustainable development. Stroebel and Wurgler (2021) emphasize that climate finance, especially through green bonds, is essential for the transition to a low-carbon economy, as it enables the mobilization of private funds for large and sustainable projects.

Adopting ESG practices can lead to productivity improvements, cost reductions, and better risk management, which can positively impact economic development (Khan, et al, 2016). Furthermore, Abate et al. (2021) suggest that strong ESG practices have a significant impact on an economy's financial performance, by encouraging higher levels of foreign investment and promoting more responsible business behavior.

(Friede, et al, 2015) show that, in the long run, strong ESG practices can have a positive impact on economic development through higher financial performance. This outcome can be achieved through increased brand value, better risk and reputation management, or improved operational efficiency. Also, the possibility of securing lower costs of capital can encourage investment in sustainable initiatives, which contribute to overall economic development.

Nicoletti et al., (2020) show that the integration of ESG factors into the investment decision-making process by companies that have a competitive advantage leads to reduced investment risk, improved governance, and increased company engagement in good social and environmental practices. On the other hand Pesaran et al., (2019) argue that the dissemination of ESG information is mainly used to increase the acceptance of improving a company's reputation among investors. Some companies also use the dissemination of ESG information as an opportunity to ease regulations from regulatory authorities regarding their investment portfolios. According to research conducted by Shkura (2019), it was observed that European countries dominated as those with the highest dissemination of ESG information globally. A key factor for this high level of dissemination in Europe is the imposition of regulations by the governments of the respective countries and stock exchanges.

According to recent studies, investors are increasingly giving importance to ESG factors in the investment selection process (Gangi et al, 2022). It has also been observed that companies that adopt ESG practices manage to generate higher profits compared to those that do not use them (Alda, 2021). One of the main reasons for this is that, nowadays, a growing number of consumers are interested in environmentally friendly products and services, as well as greener production techniques (Hole, 2019).

3 Methodology

The purpose of this paper is to analyze the impact of environmental, social and governance (ESG) performance on economic growth in Central European countries. To conduct the empirical analysis, we rely on secondary data published in the World Bank's annual reports.

The research question of this study is:

1. How has environmental, social and governance (ESG) performance influenced the economic growth of Central European countries?

While the hypothesis is:

H1: Environmental, social and governance (ESG) performance has positively impacted the economic growth of Central European countries.

This study includes data for a 10-year period (2014-2023), the number of countries included in the analysis is 8 (which are: Austria, Czech Republic, Germany, Hungary, Poland, Slovenia, Slovakia and Switzerland). The data are processed with the econometric program STATA. To verify the validity of the hypotheses of this study, we applied the following statistical tests: descriptive statistics, correlation analysis, linear regression, random effect, fixed effect, Hausman – Taylor Regression, GEE Model and GMM Model.

Table 1: Definition and description of econometric model variables

Variables	Variable description	Data source
GDP (Dependent variable)	GDP growth (annual %)	World Bank Annual Reports (2014 – 2023)
CO2 (Independent variable)	Carbon dioxide (CO2)	World Bank Annual Reports (2014 – 2023)
REC (Independent variable)	Renewable energy consumption	World Bank Annual Reports (2014 – 2023)
GEC (Independent variable)	Government expenditure on education, total (% of GDP)	World Bank Annual Reports (2014 – 2023)
CHE (Independent variable)	Current health expenditure (% of GDP)	World Bank Annual Reports (2014 – 2023)
CC (Independent variable)	Control of Corruption	World Bank Annual Reports (2014 – 2023)
GE (Independent variable)	Government Effectiveness	World Bank Annual Reports (2014 – 2023)

Source: Data processing by the author (2025)

To verify the validity of the hypotheses of this study, the following econometric model was constructed:

$$GDP_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 REC_{it} + \beta_3 GEC_{it} + \beta_4 CHE_{it} + \beta_5 CC_{it} + \beta_6 GE_{it} + \gamma_{it}$$

Where:

GDP *- GDP growth*

CO2 *- Carbon dioxide*

REC *- Renewable energy consumption*

GEC *- Government expenditure on education*

CHE *- Current health expenditure*

CC *- Control of corruption*

GE *- Government effectiveness*

γ *– stochastic variables (other factors not taken into account in the model)*

i *– code and* t *– time period.*

4 Results

In this part of the study, the validity of the hypotheses presented and the interpretation of the study findings will be verified through statistical tests for the variables incorporated in the econometric model.

Table 2 summarizes all descriptive statistics for all variables included in the econometric model.

Table 2: Summary of descriptive statistics for the econometric model variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	80	2.36	2.80	-6.31	8.38
CO2	80	7.20	1.76	4.11	10.37
REC	80	19.43	7.11	11.1	36
GEC	80	4.84	0.44	3.80	5.75
CHE	80	8.83	2.05	6.28	12.93
CC	80	0.93	0.69	-0.10	2.14
GE	80	1.07	0.53	0.22	2.13

Source: Data processing by the author in Stata program (2025)

The following will present the empirical results for the econometric model of this study, which analyzes the impact of CO2, REC, GEC, CHE, CC, GE on the GDP growth of Central European countries.

$$GDP_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 REC_{it} + \beta_3 GEC_{it} + \beta_4 CHE_{it} + \beta_5 CC_{it} + \beta_6 GE_{it} + \gamma_{it}$$

$$GDP_{it} = 2.5709 - 1.8535CO2_{it} + 0.0393REC_{it} + 1.1738GEC_{it} + 3.4965CHE_{it} + 8.4967CC_{it} + 0.8792GE_{it} + \gamma_{it}$$

Table 3: Results from the econometric model analysis

Variable	Linear Regression	Random Effects – GLS Regression	Fixed – Effects Regression	Hausman Taylor Regression	GEE Model	GMM Model
GDP	-	-	-	-	-	-.8962009*** (0.000)
CO2	-.120645* (0.074)	.110605* (0.057)	-4.420111*** (0.001)	-4.406293*** (0.000)	-.1935857*** (0.000)	-1.85359** (0.016)
REC	.0410251** (0.021)	-.0102051** (0.049)	.1071974*** (0.007)	.2686499** (0.030)	.1153579*** (0.000)	.0393677** (0.040)
GEC	.4612925*** (0.009)	.422925** (0.010)	1.008117 (0.339)	.8347343*** (0.004)	3.073826*** (0.000)	1.173858** (0.028)
CHE	-.8784762 (0.172)	.8784762*** (0.005)	.6442646* (0.051)	.540498** (0.014)	.8033199*** (0.000)	3.496511*** (0.002)
CC	.3645246* (0.080)	.1345246*** (0.001)	7.792253** (0.011)	6.080416* (0.064)	.1237373** (0.049)	8.496711*** (0.000)
GE	2.294132* (0.061)	1.214132** (0.022)	1.515735** (0.035)	3.29021** (0.031)	.9461483*** (0.000)	.8792935*** (0.008)
Const.	5.779591*** (0.002)	5.179591*** (0.000)	-36.45017** (0.021)	51.89433*** (0.004)	2.570947** (0.017)	-
R. Square	.1498	.1498	.0206	-	-	-
Adj. R^2	.0603	-	-	-	-	-

Source: Data processing by the author in Stata program (2025)
Explanation: P-values shown in brackets: *** indicates statistical significance at the 1% level; ** indicates statistical significance at the 5% level and * indicates statistical significance at the 10% level.

According to the econometric results presented in Table 3, it can be concluded that all independent variables are statistically significant at the 1%, 5%, and 10% significance levels. For the purposes of interpreting the econometric model, we will base ourselves on the GMM model.

β_0 – Assuming all other variables remain constant, the GDP is expected to be 2.57 units when the independent variables are zero (P-value = 0.017 < 0.05).

β_1 – An increase of 1 unit in CO2 emissions, while holding other variables constant, is associated with a decrease of 1.85 units in GDP (P-value = 0.016 < 0.05). With increasing temperatures and increasing diseases caused by increasing CO2 levels, the efficiency of workers is reduced, which affects the reduction of productivity and GDP. The increase in CO2 also affects climate change, increasing the intensity of natural disasters such as fires, floods and hurricanes, damaging buildings, roads, bridges, etc. From these damages, more funds must be allocated for repair and reconstruction, which reduces investments in economic development. So, with increasing CO2 levels, GDP decreases through economic and environmental mechanisms.

β_2 – A 1-unit increase in renewable energy consumption (REC), assuming other variables remain constant, leads to an increase of 0.039 units in GDP (P-value = 0.040 < 0.10). Renewable energy consumption increases productivity and economic efficiency, reducing dependence on fossil fuels and ensuring a more sustainable supply at a lower cost. The trade deficit is reduced and economic stability is improved as dependence on oil and gas imports is reduced.

β_3 – An increase of 1 unit in GEC, while keeping other variables constant, results in a 1.17 unit rise in GDP (P-value = 0.028 < 0.05). GEC has a significant impact on GDP growth. Human capital is improved by education, increasing the productivity and skills of the workforce, which affects economic growth. The more educated the population, the higher the wages tend to be, contributing more to the economy and bringing innovations that can increase a country's competitiveness in the global market. Also, investments in education reduce economic inequality and increase social mobility.

β_4 – A 1-unit increase in CHE, assuming other variables remain unchanged, leads to a 3.49 unit increase in GDP (P-value = 0.002 < 0.01). CHE affect the well-being and productivity of the population, representing an important component of GDP. Financing for investment in health care reduces future costs for treatments that can be much more costly, thus making the system more financially sustainable.

β_5 – An increase of 1 unit in CC, while keeping other factors constant, results in an 8.49 unit rise in GDP (P-value = 0.000 < 0.01). CC affects investment, public sector efficiency, and economic stability, which play an important role in GDP growth. Countries that have lower levels of corruption and countries that struggle to reduce corruption as much as possible, increase investor confidence by attracting more foreign capital, tend to have stronger institutions, use public funds better, by investing in health, education, infrastructure, etc., all of which help improve the productivity and competitiveness of the economy.

β_6 – A 1-unit increase in GE, assuming all other factors remain constant, leads to a 0.87 unit increase in GDP (P-value = 0.008 < 0.01). GE determines the ways in which public policies are implemented and how efficiently economic resources are managed, which affect GDP. The effect of government affects: improving infrastructure, education and health, maintaining fiscal and monetary stability, promoting investments, increasing tax revenues, better distribution of public funds, etc., which guarantee a sustainable and positive impact on GDP.

5 Discussion

This scientific paper focused on analyzing the impact of environmental, social, and governance (ESG) performance on the economic growth of Central European countries during the period 2014–2023. In recent years, several studies (Jolevska, et al., 2024), (Norocel & Vierescu, 2024), (Diaye et al, 2021), (Algarhi & Karimazondo, 2024), have investigated the role of ESG factors in promoting sustainable economic growth across various regions. The empirical findings of this study demonstrate that ESG practices contributed positively to economic growth in Central European countries during the observed period, underscoring the importance of ESG integration into national development strategies.

Our findings align with previous research. For instance, Jolevska et al. (2024), identified that renewable energy consumption and CO_2 emissions significantly influenced annual GDP growth in Western Balkan countries, while life expectancy at birth and labor force participation rates were key drivers of GDP growth in Southeastern Europe. Their study highlights the growing importance of the green transition as a strategic pathway toward sustainable economic development, despite its accompanying social and economic challenges.

Similarly, Norocel and Vierescu (2024), found a positive correlation between country-level ESG outcomes and economic growth, both in the short and long term. However, they noted that increased financial intermediation by the banking sector, often interpreted as a proxy for green lending activities, does not automatically translate into higher economic growth—a nuance that highlights the complexity of the ESG-growth nexus.

Diaye et al., (2021) further support this positive relationship, revealing a long-term connection between ESG performance and GDP per capita across OECD countries between 1996 and 2014, although such a relationship was less evident in the short term. Notably, exceptions such as Iceland and South Korea displayed a positive short-term relationship between ESG performance and GDP growth, suggesting country-specific dynamics.

Additionally, the study by Algarhi and Karimazondo (2024), also confirms a long-term positive relationship between ESG and economic growth, strengthening the argument that ESG integration is crucial for sustainable economic development.

Overall, the consistency between our empirical findings and previous studies reinforces the theoretical and practical significance of this research. By situating our results within the broader academic landscape, this study contributes to a deeper understanding of how ESG practices can serve as a catalyst for economic growth in Central European economies.

6 Conclusions

In accordance with the study objectives, theory, methodology, data analysis results and study findings, it can be concluded that governance effectiveness determines the ways in which public policies are implemented and how efficiently economic resources are managed, which affect GDP. Corruption control affects investment, public sector efficiency and economic stability, which play an important role in GDP growth. The consumption of renewable energy contributes to increased productivity and economic efficiency, reducing dependence on fossil fuels and ensuring a more sustainable supply at lower costs. The trade deficit is reduced and economic stability is improved as dependence on oil and gas imports is reduced. Higher investments in education have a significant impact on GDP growth. Human capital is improved by

education, increasing the productivity and skills of the workforce, which affects economic growth. Investments in health affect the well-being and productivity of the population, representing an important component of GDP. While, the increase in CO2 emissions affects: increasing temperatures, increasing diseases, climate change, increasing energy demand from extreme temperatures, etc., all of which negatively affect economic growth. So, according to these results, we conclude that the implementation of ESG factors positively affects GDP growth in Central European countries for the analyzed period 2014-2023.

Through this study, we recommend improving ESG regulations and standards, supporting businesses in implementing ESG practices, and organizing training and information campaigns for citizens and companies on the benefits of integrating ESG practices into the economy. Also, including ESG in academic programs and professional training can help create a workforce prepared for the challenges of economic sustainability. Policymakers, institutional investors, and regulators must play vital roles in assisting the Government in supporting ESG practices to create a sustainable ecosystem.

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Evaluation of the Impact of the Introduction of EN ISO 9001: 2015 in an Engineering Company

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Quality assurance is key to delivering services in the construction process, most of which are provided by engineering companies. Factors that affect quality assurance in construction services include inadequate specifications in tenders, incomplete or poor input data, inadequate communication between participants, inadequate quality control, etc. In order to achieve a high level of quality, it is important to establish a quality management system. The aim of this article is to present the basic concept for the introduction of a quality management and quality assurance system in engineering companies in accordance with the requirements of the EN ISO 9001:2015 standard. By analyzing and considering the characteristics of the company ZEU d. o. o., an assessment of the impact on the company's operations and business is made. The main findings are that the introduction of a quality system leads to the introduction of structured processes, better control of projects, a reduction in errors, improved efficiency and productivity, increased customer confidence and, last but not least, a higher reputation of the company.

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1 Introduction

Quality assurance is one of the key factors for the competitiveness and success of companies, especially in the engineering sector of the construction industry, where accuracy, efficiency and compliance with standards play a central role. In this context, the international standard EN ISO 9001 provides a comprehensive framework for establishing and maintaining a quality management system (QMS) to improve processes, increase customer satisfaction and optimize business.

ISO 9001 is an internationally recognized standard that provides for the implementation of a structured quality management system (QMS) to improve customer satisfaction and meet applicable legal and regulatory requirements. Its implementation leads to more consistent quality, improved operational efficiency and higher customer satisfaction. It generally applies to any organization, regardless of size, industry or sector.

For an engineering company, the introduction of the ISO 9001 standard is important because it enables a systematic approach to business management and control, which leads to more efficient provision of services and preparation of documentation (spatial, investment, technical and others). All this requires a well-thought-out management and organization method, appropriate control mechanisms and efficient working methods. Unfortunately, many service companies in the construction industry, especially design offices and engineering companies, do not have a QMS. They list and manage their business processes in a unique way for which efficiency and effectiveness cannot be measured (Hozjan, 2024).

The aim of the paper is to present the introduction of a QMS in the company ZEU družba za načrtovanje in inženiring d. o. o. (ZEU) and to analyze the effects of the introduction. The theoretical part presents the basic quality concepts and the philosophy of quality management, which are important for the company's business policy. The main part focuses on the introduction of the SIST EN ISO 9001:2015 standard in the ZEU and on the evaluation of the impacts of the introduction of the standard. The paper thus contributes to understanding the importance of systematic quality management in engineering companies.

2 Theoretical Background

There are several definitions of the term "quality", and different authors in different literatures cite it in different ways. The internationally recognized definition comes from the ISO 9000 standard, where the first part of the definition refers to the concepts of the overall properties and characteristics of a product or service, also known as the mix of characteristics (Bravi, Murmura, & Santos, 2019).

ISO 9000 is a set of basic principles and terminology related to QMS. It contains the basic concepts, definitions and guidelines for understanding quality management and is not intended for certification. ISO 9001 is the standard that specifies the requirements for a QMS, it is more detailed and prescriptive than ISO 9000 and is used for certification purposes. ISO 9001:2015 follows the standardized framework, which consists of ten clauses related to the following areas: Scope, Normative references, Terms and definitions, Context of the organization, Leadership, Planning, Support, Operation, Performance and evaluation, and Improvement. Organizations must implement processes, document them, and measure their effectiveness (ISO, 2015).

In order to achieve effective quality control and quality improvement, companies today often use the following modern quality management tools: TQM, 8D method, Deming circle, Ishikawa diagram, brainstorming, Pareto diagram, FMEA, 5 Why, Six Sigma, BSC (Balanced Score Card), benchmarking and others.

This paper focuses on Total Quality Management (TQM) and the associated QMS. The basic principle of TQM is based on emphasizing the importance of people, processes and results achieved. Theoretically, TQM focuses on three key areas: customer focus, continuous process improvement and extensive employee involvement (Andoljšek, 2003). In the service sector, employees are a key production factor, usually working in an interdisciplinary team with different skills and abilities. The right combination of knowledge and personality traits of team members contributes to the success of the entire team.

QMS is a system for the management and control of an organization in the area of quality. It represents a part of the organization's operational and business activities that ensures that processes are carried out in accordance with quality. Thus, it forms

the basis for the production of a quality product or the provision of a comprehensive service (Skukan & Katjuša, 2008).

3 Implementation of EN ISO 9001:2015

The quality of services is the result of comprehensive management that is customer-oriented as an organisation's management system and promotes the full involvement of all employees in continuous improvement. It is important for the company that chooses EN ISO 9001:2015 quality management to establish, document, implement and maintain a QMS and strive to continuously improve its performance in accordance with the standard's requirements. Top management must demonstrate their commitment to the development and implementation of a QMS (ISO, 2015).

As part of establishing a QMS, the company must define the processes and their application throughout the company and the sequence of processes and their interdependencies; establish methods, including criteria, for the successful operation of the processes; ensure the availability of resources or information to support the processes; monitor, measure and analyze the processes; implement measures to achieve the planned results; and implement continuous process improvement activities (ISO, 2015).

Quality management in work processes comprises planning, controlling, maintaining, and creating product or service quality. It can be divided into three levels: quality control (QC), quality assurance (QA), and quality management (QM). QC is the basic process of checking the conformity of products or services through observation and assessment using methods such as measurement, testing or comparison. Even if QC does not add value, it prevents the continued use of unsuitable products or the provision of unsuitable services. The control results can be used as feedback for previous processes or information for future processes (Šuman, 2020). The introduction of the ISO 9001 standard is limited in the paper to engineering companies in the construction industry, which are defined as micro and small enterprises under the Companies Act (The Official Gazette of the Republic of Slovenia, 2021).

4 Implementation of EN ISO 9001:2015 in ZEU

4.1 Description of the engineering company

ZEU was founded on April 3, 1974, and is headquartered in Murska Sobota. The company's services include a wide range of professional tasks, i.e. preparation of documentation in the field of geodesy and spatial informatics, project documentation, spatial planning and urban planning documentation, professional bases for spatial planning needs, investment documentation and related land acquisition, obtaining administrative approvals and permits, regulation of real estate ownership, real estate valuations and professional consulting in real estate transactions. ZEU is a multi-project company structured as a functional project management organization (Hozjan, 2024).

4.2 Impact of introduction of EN ISO 9001:2015 in ZEU

In order to implement the standard effectively, a structural analysis was first carried out in which the organizational structures, business processes and market segments that influence the company's activities and business were identified. This gave us an insight into the internal workflows, the dynamics between the different parts of the company and their impact on performance and competitiveness in the market. While introducing the standard, umbrella, main and support processes and their owners, workflows and interrelationships were identified. In addition, criteria and methods for effective process management were defined. The implementation activities were also aimed at establishing a system for measuring, monitoring and analyzing processes and defining measures to achieve the set goals. In addition to the identification and documentation of processes, ZEU also took into account the commitment of management to implement and maintain the QMS, the understanding of the requirements of the standard, the perceived need for employee training to acquire appropriate knowledge and skills and the promotion of employee participation in the implementation.

The changes in the company's business activities and an evaluation of the impact of the introduction of the standard are described in more detail below.

4.2.1 Changes in the company's operations

The introduction of the SIST EN ISO 9001:2015 quality standard entails a number of changes in the company's operations, including the adaptation of existing activities, the training and awareness-raising of employees and the establishment of a continuous improvement system.

One of the most important changes is the need to plan and document processes. This includes defining clear instructions and responsibilities for carrying out the processes and setting up a monitoring and measuring performance system. The company defined an umbrella process (management, planning and acquisition), four main processes (spatial planning, development of project and technical documentation, engineering services in the preparation and execution of investments and regulation of property relations) and a support process (common functions), which were presented with a process flow and a definition of resources.

In addition, the company has made the necessary adjustments to existing working practices and systems to ensure compliance with the requirements of the standard, including reviewing and updating existing documents and procedures.

A new organizational chart of the company was also created, namely, the introduction of a quality management manager as a joint function (Figure 1). Together with the management, this person is primarily responsible for making employees aware of the importance of quality assurance in providing their services or preparing documentation.

In addition, with the introduction of the QMS, a system of continuous improvement was also established at the level of the quality system manager, which aims to identify opportunities for improvement and measures for their implementation. However, the result of all changes is an improvement in the quality of services, a commitment to continuous progress and the adaptation of processes to changing market conditions and customer needs.

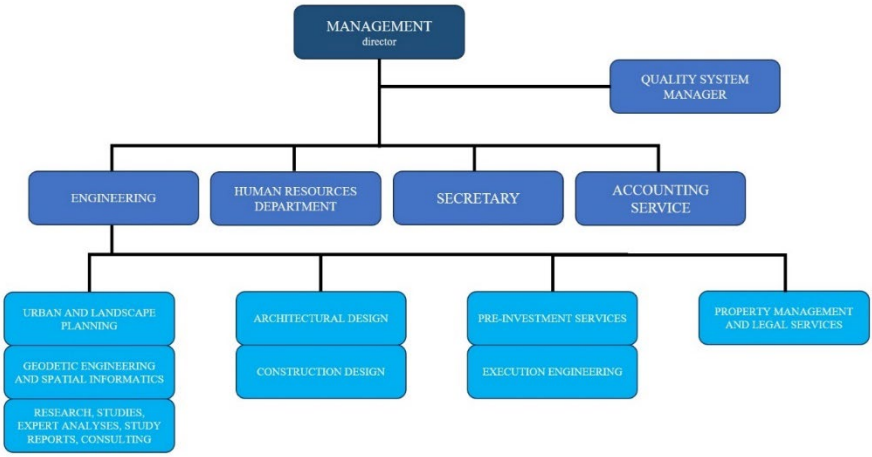

Figure 1: New organizational chart of ZEU

4.2.2 Evaluation of the impact

The impacts of the introduction of EN ISO 9001:2015 are generally divided into financial (impact on company revenues, assets, costs, etc.) and non-financial (impact on customers, employees, company performance, organization of processes, etc.) and are as follows for the ZEU:

- improving process synchronization (coordination, structuring and efficiency), which leads to an increase in the quality of services and their projects;
- by focusing on meeting the needs and expectations of customers, their satisfaction increases, which is the key to attracting new customers and retaining existing ones;
- as the number of customers increases and the quality of services improves, the company's revenue increases;
- EN ISO 9001:2015 promotes the analysis and continuous improvement of processes and thus increases the efficiency of design, planning and project implementation services;
- QMS helps to identify and manage risks, reducing the occurrence of potential negative impacts on projects;

- the introduction of EN ISO 9001:2015 helps a company to work systematically and in accordance with professional rules, legislation and other regulations;
- the QMS enables greater transparency and a clear definition of responsibilities within the company, which contributes to better internal communication and easier decision-making;
- clearly defined processes and responsibilities enable better management of projects;
- the quality assurance system reduces the possibility of errors and irregularities in projects, which helps to reduce the number of complaints and/or the need for corrections, which in turn means lower costs for the company;
- the regular and organized training and further education of employees leads to greater work efficiency and satisfaction, which has a positive effect on employee motivation and lower staff turnover;
- the increased bureaucracy associated with the introduction of the standard can lead to lower employee satisfaction;
- the introduction of EN ISO 9001:2015 and certification will enhance the company's reputation and improve its competitive position;
- the QMS introduced and the certificate obtained demonstrate that the company operates in accordance with the standards and procedures, which strengthens customer confidence in the company's ability to provide a high level of service quality.

In general, the introduction of EN ISO 9001:2015 has numerous positive effects, which are primarily reflected in improved service quality, higher customer satisfaction, better project management and greater transparency of processes and responsibilities within the company. However, it is also important to understand the potential challenges that arise for the company, such as additional workload for employees, higher implementation costs, changes in working habits and limited flexibility and creativity in some processes.

5 Discussion

A well-prepared QMS resulting from the implementation of the EN ISO 9001:2015 standard has a significant impact on the engineering company by reducing the occurrence of errors, weaknesses and deficiencies in the design, planning and project

implementation services. At the same time, the obtained certificate can be a good marketing tool for companies to create a good image and expand the company to other markets. Table 1 summarizes the basic characteristics of introducing a QMS in an engineering company in general, based on a SWOT analysis.

Table 1: SWOT analysis of the introduction of QMS in an engineering company

STRENGTHS	WEAKNESSES
– better ability to comply with legal requirements and regulations, – better participation in public procurement, – better access to advanced technological knowledge, – better risk management and planning, – lower costs (rationalization), – greater competitiveness, – interoperability between new and old services and processes, – better management of processes, – continuous quality improvement, – better management of documentation.	– costs for the introduction of a QMS and certification, – increased bureaucratic effort due to more extensive documentation, – need for additional education and training of employees, – inconvenience for employees due to changes in working habits.
OPPORTUNITIES	**THREATS**
– strengthening the company's reputation and position on the market, – increase of the business influence, – increasing the satisfaction of employees, customers and partners, – easier expansion into new markets and the development of new market niches, – competitive advantage, – opportunity to innovate processes and approaches in design and construction (IT tools, BIM approach, Industry 4.0 tools).	– hesitation in the introduction of standards, – unmotivated employees, – lack of understanding of the QMS, – unusable QMS documentation, – adverse impact on the business than expected, – possible extension of time to complete a task or project due to the need to implement procedures consistently, – increased workload of employees.

Overall, we can conclude that the implementation of the ISO 9001:2015 standard in engineering companies brings numerous benefits, which are reflected in improved service quality, higher customer satisfaction, more efficient project management, and greater transparency and accountability within the organization. The system ensures compliance with the standards, but also represents an opportunity for the organization to take a leading role in the market and leverage competitive advantages.

Despite the tangible positive effects, it is also important to recognize the challenges that the introduction of the standard can bring. These include additional burdens for employees, new costs due to implementation, changes to working practices and restrictions on flexibility and creativity in some processes.

Implementation may also lead to inadequately prepared documentation of the quality system, an extension of the implementation time of the task or project, and even the occurrence of effects that are opposite to what is expected of the business. Therefore, it is important for small and medium-sized companies, where most engineering and consulting companies operate in the field of construction, to be aware of all the benefits but, above all, the challenges.

6 Conclusions

Quality assurance is crucial to the successful operation of engineering companies, especially in the construction process. Quality of service must be integrated into all phases of the project lifecycle, with the key being the early detection and correction of errors. In addition, it is important to meet market and client requirements, considering the fundamental requirements of the construction industry. A well-established quality assurance and management system in an engineering company, resulting from the introduction of the EN ISO 9001:2015 standard, has a significant impact on the quality-of-service delivery (design, planning, supervision) and thus creates the customer's trust that the ordered services will achieve the planned (expected) quality.

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A Comprehensive Examination of the Impacts of the Circular Economy Within the ESG: Evaluating New Metrics and Interactions

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This paper provides an examination of the impacts of the circular economy within the framework of ESG criteria, emphasizing the interplay between these domains. The research aims to explore how circular economy principles can enhance ESG performance while identifying synergies and trade-offs across the three pillars. A methodology leveraging European Union datasets and indicators is applied, comparing to the ESG performance values of individual European Union member states. The findings indicate that integrating circular economy practices into ESG strategies enhances environmental outcomes, such as resource efficiency and waste reduction, while fostering social equity and improving governance transparency. However, challenges related to metric standardization and data harmonization across regions present limitations. The paper provides implications for policymakers, businesses, and investors by offering a framework for embedding circular economy principles within ESG strategies to drive sustainable development. The novelty of the research lies in the use of the first coherent and comprehensive index database for comparisons, leveraging European Union data to deepen the understanding of the relationships between circular economy principles and ESG (environmental, social, and governance) domains. By addressing a gap in the literature, this work contributes to the development of actionable tools for assessing and improving sustainability practices across industries.

Keywords:
circular economy, sustainability, ESG, performance metrics, impact assessment

JEL:
C43, O13, Q56

University of Maribor Press

1 Introduction

The circular economy (abbreviation: CE) has gained significant attention in recent years as a potential solution to the environmental and economic challenges posed by traditional linear production and consumption models (Geissdoerfer et al., 2017). This popularity stems from its capacity to bridge production and consumption at the system, technological, and product levels (Morseletto, 2023). This approach primarily aims to maintain products, components, and materials at their highest utility and value for as long as possible, thereby minimizing waste and maximizing the efficient use of resources throughout their lifecycle. By promoting the circularity of materials and products, this approach seeks to reduce reliance on virgin resources and enable a more sustainable and regenerative economic model. The central aim of the CE is to develop innovative approaches that sustain products, components, and materials at their optimal utility and worth throughout their entire lifecycle, while generating long-lasting and sustainable economic, environmental, and social benefits for the wider societal system (Ranta et al., 2020). By adopting CE principles, businesses and communities can minimize waste, conserve natural resources, and create closed-loop systems that continuously recycle and reuse materials (Bódizs, 2022), thereby reducing their environmental impact and contributing to a more sustainable future (Ranta et al., 2020). Implementing the CE can catalyze relevant social, technological, institutional, and economic changes that intersect with various aspects of the sustainability transition, such as business model innovation, institutional roles, and governance rules and instruments (Urbinati et al., 2017). As the CE concept continues to evolve, it is essential to understand its impacts on the Environmental, Social, and Governance (abbreviation: ESG) metrics that are increasingly used to evaluate the sustainability and responsible business practices of organizations (Kyriakopoulos, 2021). Although the CE has been extensively examined from an environmental and economic standpoint (García-Barragán et al., 2019), its integration within the broader Environmental, Social, and Governance framework remains a topic that has received relatively less scholarly attention.

2 Theoretical Background

Corporate efficiency, or the CE, and ESG disclosures are two interconnected concepts that have gained significant attention in recent years (Khamisu & Paluri, 2024; Nyantakyi et al., 2023). The CE, which emphasizes the efficient use and reuse

of resources, is closely aligned with the environmental aspect of ESG, as it aims to reduce waste, emissions, and environmental impact (Khan, 2024; Sánchez-García et al., 2024). At the same time, the social and governance components of ESG, such as corporate social responsibility and ethical practices, can serve as enablers for the transition to a more CE (Santiago et al., 2025). The CE, which emphasizes the efficient use and reuse of resources, is closely aligned with the environmental aspect of ESG, as it aims to reduce waste, emissions, and environmental impact (Khan, 2024). At the same time, the social and governance components of ESG, such as corporate social responsibility and ethical practices, can serve as enablers for the transition to a more CE (Palea et al., 2024). One key aspect of the relationship between CE and ESG is the issue of "greenwashing", where companies may misrepresent their environmental practices to appear more sustainable than they truly are (Abouarab et al., 2024). This can undermine the credibility of both the CE and ESG disclosures and highlights the importance of transparent and verifiable reporting on sustainability measures (Dempere et al., 2024). The transition from a linear "take-make-dispose" model to a more circular approach is not without its challenges (Chirumalla et al., 2024). Small and medium-sized enterprises may face barriers in adopting CE practices, such as a lack of resources or knowledge (Mishra et al., 2022). However, the potential benefits of the CE, both in terms of environmental impact and economic gains, make it an increasingly attractive proposition for businesses of all sizes (Knäble et al., 2022). As research on the CE continues to evolve, it will be important to consider the broader context of ESG and how these two concepts can be mutually reinforcing in driving sustainable business practices (Sánchez-García et al., 2024). This includes examining the ways in which the environmental, social, and governance factors that comprise ESG can enable and support the transition to a more circular economic model (Khan, 2024). For instance, strong corporate governance and transparency around sustainability metrics can help build trust and credibility in CE initiatives, while social responsibility programs that prioritize community engagement and worker welfare can facilitate the adoption of circular practices (Zhang & Hao, 2024). Ultimately, a comprehensive understanding of the linkages between CE and ESG will be crucial in developing holistic strategies for achieving long-term sustainability in business operations (Garcia-Saravia Ortiz-de-Montellano et al., 2023). ESG factors are all crucial components of the CE, and a holistic approach that considers the interplay between these elements will be key to realizing the full potential of this shift towards a more sustainable future (Kyriakopoulos, 2021; Yu et al., 2020).

3 Methodology

The paper employed a methodological approach that leveraged Eurostat's existing circular economy indicators to analyze the interplay between circular economy principles and environmental, social, and governance performance. Instead of creating new composite indicators, the research focused on exploring the relationships between the circular economic utilization rate and individual countries' ESG index values, providing valuable insights into their interconnections and interactions.

3.1 Data

This research employs Eurostat's comprehensive CE indicators (Eurostat, 2025), with the circular material use rate as a key measure incorporated in the study. By incorporating the most up-to-date data available, spanning multiple years, the study ensures a robust and relevant analysis of the prevailing trends and conditions. The utilized ESG Index (Risk Watch Initiative, 2025) assesses the environmental, human rights, and health & safety performance of 183 countries using 65 variables. Countries are scored on a scale from 0 to 100, with 0 representing the lowest risk and 100 the highest. This index helps organizations implement effective CSR policies and align with ESG regulations.

3.2 Methodology for analysing interrelationships

The methodology centers on evaluating the interrelationships between circular economy indicators and ESG index values across European Union (abbreviation: EU-27) member states. By comparing the circular material use rate with ESG performance metrics, the study identifies synergies and trade-offs within and between the environmental, social, and governance dimensions. These relationships were analyzed using statistical tools and data visualization techniques, offering a comprehensive framework for assessing the impact of circular economy practices on ESG outcomes. The study explores how the implementation of circular economic principles can influence and shape the environmental, social, and governance aspects of business operations and national policies within the EU-27. Through in-depth analysis, the researchers provide insights into the potential

synergies and tensions that may arise as organizations and governments strive to achieve both operational efficiency and sustainable, responsible practices.

4 Results

The analysis of circular material use and ESG indices across various countries reveals intriguing insights regarding the relationship between these two metrics and their potential impact on sustainable development. The countries with the highest circular material use ratios are Holland, Italy, and Malta. These nations also show relatively strong ESG indices, with Holland scoring 22.61, Italy at 25.73, and Malta at 26.10. The correlation between high circular material use and robust ESG indices indicates a potential synergy between material circularity and overall sustainability performance. This synergy suggests that a focus on circular material use may contribute to the achievement of broader environmental, social, and governance objectives, leading to more holistic and impactful sustainability initiatives. On the other hand, countries with low circular material use rates such as Finland, Ireland, and Romania present a paradox in their ESG indices. Finland, with a modest circular material use rate, exhibits a notably low ESG index, while Ireland's ESG index is higher despite a similar circular material use. Romania, while having the lowest circular material use rate, has a relatively higher ESG index, suggesting that the country's broader sustainability initiatives may not yet be fully reflected in its circular economy performance. This discrepancy highlights the need for further investigation into the factors influencing the disparity between circular economy metrics and ESG indices. Specifically, this discrepancy suggests that ESG indices may not fully capture the nuances of a country's circular economic efforts, and that a deeper examination of the relationship between circular economy metrics and broader sustainability indicators is warranted. By understanding the complex interplay between these factors, policymakers and researchers can gain a more comprehensive view of a country's environmental, social, and governance performance. Analysis of the countries with the highest ESG scores, such as Hungary, Bulgaria, and Romania, reveals a mismatch between their ESG performance and circular material use. Despite having notable ESG scores, Hungary and Bulgaria exhibit very low circular material use rates of 5.9% and 4.9%, respectively. This indicates that while these countries excel in other areas of sustainability, their circular economy strategies may be underdeveloped, potentially hindering their progress towards comprehensive sustainability goals.

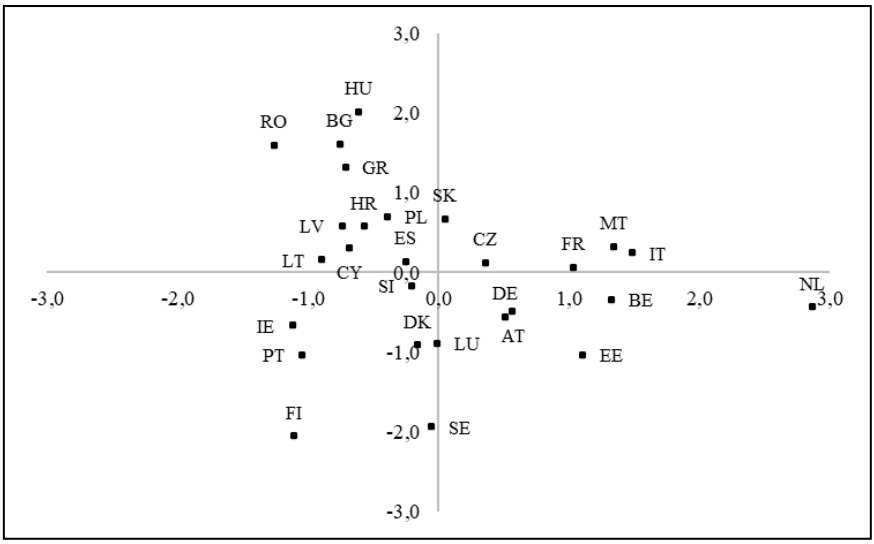

Figure 1: Relationship between ESG index and circular material use rate for EU-27.

The countries with the lowest ESG indices, such as Finland, Sweden, and Portugal, represent some of the best ESG performers globally. Finland, despite its relatively low circular material use rate, excels in other key sustainability measures, likely due to its strong environmental policies, high levels of innovation in sustainable technologies, and effective waste management strategies. Sweden's low ESG index further supports this notion, as the country is widely recognized as a leader in renewable energy generation and sustainable business practices, although its circular economy metrics may still be gradually improving. Similarly, Portugal, with a modest ESG score of 19.87, demonstrates that a country can achieve notable ESG success through comprehensive efforts across social, environmental, and governance dimensions, even if its circular economy practices are still evolving and maturing.

5 Discussion

The relationship between ESG performance and circular economy is complex and multifaceted. Circular material use can have a positive impact on economic development and resilient growth, reducing dependency on resource markets and exposure to resource price shocks (García-Barragán et al., 2019). However, the transition to a circular economy model necessitates profound transformations in existing production and consumption patterns, which can have far-reaching social

implications that must be carefully considered and addressed. However, it is important to recognize that high ESG performance is not solely contingent on circular economy metrics, as a multitude of other factors, such as a country's commitment to innovation, the strength of its governance structures, and the comprehensiveness of its environmental policies, also play a pivotal role in shaping overall sustainability outcomes. Countries with high circular material use tend to have stronger ESG indices, as circular economy principles can promote environmental protection, social responsibility, and robust governance practices (De Pascale et al., 2021). However, the connection between circular material use and ESG indices is not entirely linear. As highlighted in the literature, countries with high circular material use, such as Hungary and Bulgaria, tend to have stronger ESG indices. This suggests that improving circular material use could enhance ESG performance, leading to improved environmental protection, social responsibility, and robust governance practices (García-Barragán et al., 2019).

6 Conclusions

In conclusion, while there is some correlation between circular material use and ESG indices, the relationship is complex and not entirely linear. Countries with high circular material use do tend to have stronger ESG indices, but other factors, such as innovation, governance, and environmental policies, also play a significant role in shaping these outcomes. For countries like Hungary and Bulgaria, improving their circular material use could further enhance their ESG performance, potentially leading to improved environmental protection, social responsibility, and robust governance practices. On the other hand, nations like Finland and Sweden demonstrate that high ESG indices are achievable through holistic sustainability strategies, even with lower circular economy metrics, by prioritizing a diverse range of sustainability initiatives beyond just material circularity. The interplay between circular material use and ESG performance is multifaceted, with various socioeconomic, political, and environmental factors contributing to the overall sustainability outcomes of a country. A comprehensive approach that addresses not only material circularity but also innovation, governance, and environmental policies is crucial for achieving meaningful and lasting progress in environmental, social, and governance practices. The paper is limited by its reliance on secondary data, constraining the ability to establish causal relationships; addressing this through the integration of primary data and a deeper exploration of indicator relationships and

standardization challenges could provide a more holistic understanding of the interplay between circular economy practices and ESG performance.

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The Potential of Artificial Intelligence in Addressing Climate Change

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Artificial intelligence (AI) has become an instrumental technology in the fight against climate change, especially in industrial and corporate settings. This study specifically explores how businesses within the facilities management sector have integrated AI technologies to mitigate and adapt to climate challenges. Four expert interviews with corporate leaders who have successfully deployed AI solutions were conducted to identify key challenges, barriers, and success factors in implementing AI-driven climate solutions, and develop recommendations for businesses seeking to leverage AI for climate action. The findings of this study highlight the significant potential of AI in addressing climate change challenges within the facilities management sector, including demand response management, predictive maintenance, smart building optimization, and supply chain decarbonization. Demand response management has effectively reduced peak load stress and significantly lowered annual CO_2 emissions, while predictive maintenance has contributed to a noticeable reduction in energy waste and an extension of machinery lifespan. Key results include the substantial environmental benefits achieved through targeted AI interventions in energy management and the risk mitigation gained from gradual implementation strategies.

Keywords:
artificial intelligence, sustainability, emission, predictive maintenance, smart building

JEL:
O33, Q54, Q56

University of Maribor Press

1 Introduction

This study investigates the integration of artificial intelligence in corporate climate strategies, addressing the dual challenge of global warming and technological adaptation through AI-driven solutions in energy and resource management. Another challenge is the proper use of AI applications in addressing climate change, including demand response management, predictive maintenance, smart building optimization, and supply chain decarbonization. These two fields together show the urgent need to articulate new solutions by academics and professionals. For instance, July 2023 was recorded as the hottest month in human history, with the nine warmest years ever documented occurring within the last decade (Moustafa et al., 2023). Severe storms, droughts, floods, and wildfires – all amplified by global warming – have caused extraordinary damage worldwide, while sea-level rise threatens coastal communities globally (Varga & Csiszárik-Kocsir, 2023). Despite the Paris Agreement's call to limit global temperature increases to well below 2°C above pre-industrial levels, the world remains on track for approximately 3°C warming by 2100 (Warren et al., 2022). Not to mention that around 4 billion people already live in areas highly susceptible to climate change, and there are many areas with weak health infrastructure – mostly in developing countries – that will be the least able to cope without assistance to prepare and respond (WHO, 2025).

Climate change affects our health in many ways. It can cause death and illness by disrupting food systems and contributing to mental health problems. Additionally, it weakens important factors for good health, such as jobs, fairness, access to healthcare, and support from our communities (Figure 1). These impacts tend to hit the most vulnerable people the hardest, including women, children, ethnic minorities, poor communities, migrants or those displaced, older adults, and people with existing health issues (McMichale et al., 2011; Rawat et al., 2024).

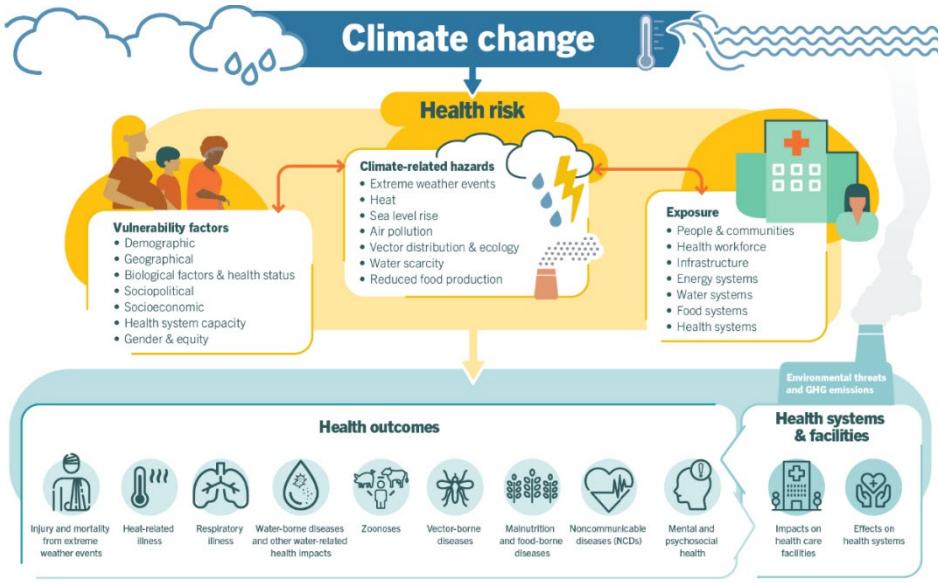

Figure 1: An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors
Source: WHO (2025), Available at: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

Figure 1 shows that climate change is presented as a main factor influencing health outcomes through several interconnected elements. Vulnerability factors – such as demographics, geography, socioeconomics, and health system capacity – increase the risk of climate-related hazards like extreme weather, heat, and air pollution. These hazards, in turn, affect people, systems, and communities, creating various exposures and leading to a broad range of health issues, including injuries, illnesses, malnutrition, and mental health challenges. Additionally, the figure also shows how health systems are both impacted by environmental threats and essential in addressing these risks. Disruptions to health facilities can worsen existing inequalities, since vulnerable groups often face greater challenges in accessing care. This highlights the need for stronger and more adaptable healthcare structures.

Based on the abovementioned examples, it can be stated that climate change affects humanity both physically and mentally (Szeberényi, 2023). Hence, this trajectory demands urgent, innovative solutions that transcend conventional approaches. On the technological side, however, artificial intelligence has experienced unprecedented growth and advancement. Many scientists – Fauville et al., 2020; Jain et al., 2023;

Sundberg, 2024; Berde et al., 2025 – mention the urgent need of AI tools and models to tackle the heavy climate change issues. This indeed will be mandatory soon, and we agree with the idea of Lim (2019, p. 814), *who said "AI has become a cornerstone of innovation that will be the defining technology of our time"*. In 2025, these words could not be more pertinent because AI has begun transforming nearly every major industry through its capacity to analyse vast datasets, identify complex patterns, and generate novel solutions. The convergence of these two global phenomena – climate crisis and technological revolution – presents both significant challenges and extraordinary opportunities for addressing one of humanity's most complex problems.

2 Theoretical Background

Artificial intelligence offers unique capabilities particularly suited to addressing climate change challenges. Climate science inherently involves complex systems analysis, vast data processing requirements, and multivariable prediction – all areas where AI excels. The technology's ability to process enormous datasets and identify non-obvious patterns makes it especially valuable for climate modelling, emissions tracking, and optimization of resource-intensive systems.

Recent advances in AI have enabled significant improvements in climate forecasting, greenhouse gas monitoring, and energy optimization. For instance, AI is improving climate model performance, providing advanced warning of extreme weather events, and helping attribute such events to atmospheric changes.

In the domain of emissions monitoring, AI systems now draw on data from satellites, aircraft, drones, and ground-based sensors, offering sharper insight into greenhouse gas sources than ever before. Meanwhile, these same technologies can measure the melting rates of glaciers and icebergs and identify exactly where melting is occurring (WEF, 2023). Such capacities are remarkable: AI can track iceberg changes up to 10,000 times faster than a human analyst, thereby enhancing our understanding of how much meltwater these ice masses release into the oceans – an issue growing more urgent as climate change warms the atmosphere Scientists at the University of Leeds in the United Kingdom, according to the European Space Agency, report that their AI tools can map large Antarctic icebergs in satellite images in as little as one-hundredth of a second. By contrast, human efforts remain slow

and prone to error, especially when distinguishing icebergs from the surrounding whiteness of clouds and sea ice (ESA, 2023).

Another notable area where AI demonstrates exceptional utility is in the precise mapping of environmental changes. AI significantly enhances environmental monitoring by enabling the precise mapping of deforestation. By combining satellite imagery with the ecological expertise of researchers, AI systems effectively delineate deforestation areas and assess its impact on the climate crisis. This integrated approach allows for the accurate measurement of both the extent of forest loss and the quantification of carbon dioxide stored within forest ecosystems (WEF, 2024). Moreover, AI demonstrates considerable potential in the realm of waste recycling, and debris detection – a field critical to mitigating climate change (Figure 2).

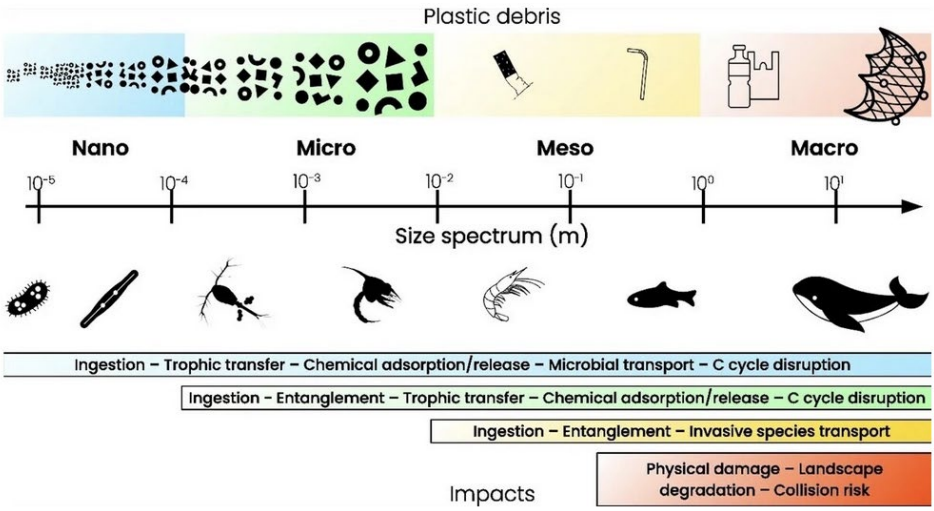

Figure 2: Categories of plastic debris analysed by AI and their impact on the environment
Source: Ocean Cleanup (2023). Available at: https://theoceancleanup.com/updates/lasting-damage-why-cleanup-is-essential-to-tackle-microplastics/

The United States Environmental Protection Agency identifies waste as one of the largest sources of methane emissions, contributing approximately 16% to global greenhouse gas outputs. In response, Greyparrot, a London-based software startup, has developed an AI-driven system to analyse waste processing and recycling facilities (Greyparrot, 2025). This system aids in recovering materials that would otherwise be lost to landfills. In 2022, the company monitored 32 billion waste items

across 67 categories and reported that, on average, it could identify 86 tonnes of recyclable material that might otherwise have been discarded (Greyparrot, 2022). These developments demonstrate AI's capacity to enhance the efficiency and precision of environmental monitoring and waste recovery processes.

3 Methodology

Despite growing recognition of AI's potential contributions to climate mitigation and adaptation, substantial gaps remain in understanding how these technologies are being implemented in 'real-world business' contexts. While theoretical capabilities have been extensively documented, less research exists on the practical challenges, financial implications, and operational realities of deploying AI for climate solutions within corporate environments. This research addresses this knowledge gap by investigating how businesses are integrating AI technologies into their operations specifically to address climate-related challenges. Through four expert interviews with corporate leaders who have successfully deployed AI solutions, we examined the practical applications, implementation challenges, and measured outcomes of these technologies. This study aims to provide insights beyond theoretical potential, offering a grounded perspective on AI's current and near-future contributions to corporate climate action.

The main objective of this research was to identify key challenges, barriers, and success factors in implementing AI-driven climate solutions, and develop recommendations for businesses seeking to leverage AI for climate action.

To achieve this objective, we addressed the following research questions:

Q1: What are the primary applications of AI being deployed by businesses to address climate change?

Q2: What best practices can be identified for organizations seeking to implement similar solutions?

4 Results

To find our answer to the first research question (Q1), the expert interviews revealed four dominant AI applications in corporate climate strategies:

1. Demand response management emerged as a critical tool for energy-intensive industries. A utility sector executive noted: *"Our AI system analyses weather patterns, grid loads, and historical consumption data to dynamically adjust energy distribution. This reduced peak-load stress by 27% and cut annual CO_2 emissions by 7,500 metric tons"*.
2. Predictive maintenance showed significant adoption in manufacturing. One of the interview participants who is an automotive leader mentioned that *"By deploying vibration sensors and machine learning, we predict equipment failures 48 hours in advance. (…) This lowered energy waste from unplanned downtime by 26% while extending machinery lifespan by 33%"*.
3. The other interviewee was a property tech CEO, who specialized in smart building optimization. In the interview he mentioned that *"Our AI-driven HVAC systems adjust in real-time to occupancy sensors and external temperatures, achieving an estimated 20% energy savings across 60,000 square feet of commercial space"*.
4. The fourth participant was a logistics director who is an expert in supply chain decarbonization. He mentioned related to our preliminary stated research question that *"The new route optimization AI-algorithms reduced fleet emissions by 14% without compromising delivery times, while material selection AI cut packaging waste by 48%"*.

It was also necessary to ask these experts about the best strategies that they believe have proven vital for success. Related to our second research question (Q2) we can summarize their thoughts as follows:

- *"Starting small with a single production line before company-wide rollout can reduce the technical risks. (…) AI helped in that too."*,
- *"Keep your workforce and enhance their knowledge (…) training existing engineers in AI literacy rather than wholesale replacements can improve not only the system, but the adoption rates by a high degree"*.
- *"If possible, collaborate with climate startups as early as possible. (…) They know best the key leading problems in macro levels"*.
- *"Share the operational data with external AI developers and experts (…) In our case this method accelerated the solution tailoring by 4 months which is very long timeframe when we talk about AI technology"*.

Summarizing the most relevant results, it can be concluded that the questioned experts mentioned four different AI application possibilities in corporate strategies which are analysation with AI, use of Machine Learning to predict equipment failures, use of AI-driven HVAC system and AI-algorithms in route optimization. In their opinion the best strategies for success are to starting small with a single production line, enhance the knowledge of the workforce, collaborate with climate startups and share operational data with AI developers.

5 Discussion

The findings of this study highlight the significant potential of AI in addressing climate change challenges within the facilities management sector. The identification of regulatory compliance and responsible supply chain as key drivers aligns with previous research emphasizing the role of governance in promoting sustainable practices (Jain et al., 2023; Pap et al., 2025). However, the emergence of policy constraints and energy crises as major barriers underscores the complex interplay between technological adoption and contextual factors, particularly in developing nations (Vinuesa et al., 2020; Berde et al., 2025). The multiple pathways identified for achieving high levels of technological transformation and policy adaptation through AI commitment dimensions resonate with the configurational perspective proposed by Gazzotti et al. (2021). This suggests that a nuanced, context-specific approach is necessary when implementing AI solutions for climate action, rather than a one-size-fits-all strategy. And it should not be forgotten that not only the business, but other sectors, like higher education, is also facing new challenges regarding how to effectively exploit the AI's potential (Folmeg et al., 2024). The critical role of digital skills and climate policy readiness across successful pathways emphasizes the need for comprehensive capacity-building programs. This finding aligns with the growing body of literature on the importance of human capital and institutional readiness in leveraging AI for sustainable development (Rolnick et al., 2019).

6 Conclusion

This study has effectively fulfilled its objective of identifying and analysing the roles of AI in corporate responses to climate change. Based on four expert interviews with leaders from diverse industries, the findings reveal four primary applications:

demand response management, predictive maintenance, smart building optimization, and supply chain decarbonization. These strategies have yielded tangible outcomes, including reduced CO_2 emissions, improved energy efficiency, and extended equipment longevity. The utility sector executive emphasized the proactive nature of AI in energy management, saying *"our AI platform doesn't just respond to peak loads, it can forecast them. (…) Allowed us to reduce grid stress and cut emissions during high-demand periods"*. From the automotive industry, the expert highlighted efficiency and reliability, mentioning *"predictive maintenance using AI fundamentally changed our downtime strategy"*. The property tech CEO shared insights into smart infrastructure highlighting that *"the used AI-driven building systems are helping to respond in real-time to occupancy and environmental inputs, improving sustainability metrics and occupant satisfaction"*. Lastly, the logistics director pointed out that *"(…) by integrating AI into both routing and packaging logistics, we not only reduced fleet emissions but also cut packaging waste significantly"*. These firsthand accounts underscore AI's diverse role as a technological enhancement and strategic enabler for climate resilience. The best practices identified – for instance: phased implementation, workforce upskilling, early collaboration with climate-focused startups, and open data exchange – provide actionable pathways for organizations seeking to adopt AI for environmental goals. Future research should investigate AI deployment across additional sectors such as agriculture, public infrastructure, and urban planning, where diverse operational contexts may reveal unique challenges and opportunities. Additionally, longitudinal studies tracking AI's environmental performance over time could help refining the best practices and create comparisons to adaptive policy frameworks.

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THE IMPACT OF REGULATION ON CSR: AN ASSESSMENT OF CSRD COMPLIANCE AND THE IMPLICATIONS OF THE OMNIBUS REGULATION

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Aim: The research paper focuses on the analysis of sustainability regulation and its impact on corporate sustainability reporting in practice. In particular, it examines in detail the extent to which the CSRD influences corporate sustainability reporting in practice and the impact that the upcoming Omnibus regulation will have on corporate sustainability reporting. **Methodology:** To analyze the level of sustainability reporting in practice, multiple case studies will be conducted based on selected companies, using the content analysis method. **Findings:** The research results indicate that companies report sustainability information in line with the requirements set by the CSRD. It is observable that the most detailed reporting is found in the social domain. Based on the research findings, it can be concluded that the existing NFRD and CSRD have influenced the level of sustainability reporting in practice. With the upcoming Omnibus regulation, which is expected to ease reporting requirements in practice, an impact on sustainability reporting is anticipated. **Value:** The main value of this research paper lies in the investigation of the impact of sustainability reporting legislation on sustainability reporting in practice. More specifically, the research examines the upcoming CSRD and the Omnibus regulation, analyzing how legislation influence is reported.

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1 Introduction

In recent months, a significant need has emerged in the field of sustainability reporting for the assessment of the existing CSRD ruling which defined and standardized the reporting of corporate sustainability information. Since 2017, considerable efforts have been observed to establish harmonized and comprehensive sustainability reporting. This has been reflected in the implementation of the Non-financial Reporting Directive (hereinafter NFRD) and afterward the Corporate Sustainability Reporting Directive (hereinafter CSRD). CSRD also introduced the reporting standards ESRS, which define in greater detail the format and types of information that companies must report. These standards provide companies with guidelines and definitions on the direction they should take and the information they must disclose. In this respect, a significant step has been taken towards ensuring standardized sustainability information re-porting. However considering the current development of global events, these changes have been identified as a potential cause of uncompetitive business in the EU. Therefore, the EU has witnessed initial efforts related to the so-called Omnibus regulation, which foresees legislative changes and a partial easing of existing CSRD requirements. This paper aims to assess the extent to which selected companies report CSRD information in their annual reporting (based on a predefined research model) and to reassess to what extent the upcoming Omnibus regulation could change corporate governance and the reporting of sustainable information practice (Čufar & Primec, 2022; Papathanassiou & Nieto, 2025; Saam & Rosenstein, 2024).

2 Theoretical Background/Literature review

The CSRD is designed to enhance the transparency and quality of sustainability reporting. Compared to its predecessor, the NFRD, it introduces stricter measures, standardized reporting, and the disclosure of additional sustainability-related information, such as business models, strategies, risks, and opportunities. The CSRD implements standardized reporting and the audit of reported data while also introducing the double materiality concept and other improvements. The double materiality concept requires companies to report both on how sustainability factors impact their financial performance and on how their business activities affect the environment and society. The CSRD came into effect on January 5, 2023, and EU Member States were required to transpose it into national legislation by July 6, 2024.

The main objective of the directive is to improve transparency and comparability in sustainability data reporting. It enhances and addresses the shortcomings identified in the NFRD directive. The disclosures that companies must report relate to ESG information following the ESRS reporting standards. The standards are divided into 12 standards, categorized into three ESG areas. Additionally, detailed sector-specific standards will be prepared for global consolidated reporting of companies outside the EU, as well as simplified standards for SMEs and smaller, less complex institutions. Economic entities will also be required to report on their entire value chain, including both indirect and direct business relationships within the supply chain and distribution network. The main purpose of the directive relates to the high-quality collection of data (Čufar et al., 2024; Primec & Belak, 2022).

The EU has initiated a debate on simplifying sustainability reporting regulations with the Omnibus regulation. The proposals are based on reasons arising from geopolitical pressures and the enhancement of the competitiveness of European companies. It assumes and proposes that the mandatory reporting required by the standardized reporting framework under the CSRD should be reduced, introducing a transition to voluntary disclosure of information. The Omnibus regulation suggests postponing reporting obligations and introduces new rules where companies would be required to report only if they have more than 1,000 employees, annual revenue exceeding EUR 50 million, or a balance sheet total above EUR 25 million. This would significantly reduce the number of companies subject to mandatory reporting under the CSRD. The Omnibus regulation further proposes that, alongside the mandatory ESRS standards, VSME standards be introduced, which would provide voluntary reporting standards that are less detailed than the ESRS. Such measures are intended to reduce the burden on companies while, at the same time, increasing their competitiveness. The Omnibus regulation represents a new legislative framework that introduces amendments to several different legislative acts. The main objective of the new Omnibus regulation is to enhance competitiveness and mobilize new financial capacities. It aims to implement changes in areas, such as sustainable finance reporting, due diligence processes, the EU taxonomy, the carbon border adjustment mechanism, and EU investment programs.

The Omnibus regulation comprises multiple documents and legal acts. Among the proposed legal acts included in the Omnibus regulation is the *Proposal for a Directive of the European Parliament and of the Council amending Directives 2006/43/EC,*

2013/34/EU, (EU) 2022/2464 and (EU) 2024/1760 as regards certain corporate sustainability reporting and due diligence requirements. Another is the *Proposal for a Directive of the European Parliament and of the Council amending Directives (EU) 2022/2464 and (EU) 2024/1760 as regards the dates from which Member States are to apply certain corporate sustainability reporting and due diligence requirements*.
(Pasqua, 2025).

Past research highlights that CSR is based on two methodological approaches. The first approach, descriptive studies, focuses on the nature of disclosure while the second approach focuses on explanatory studies of factors influencing sustainability reporting. Research reveals that corporate reporting differs between countries and confirms that the quality of sustainability reporting following CSRD requirements is influenced by corporate characteristics, governance mechanisms, and external factors (Khan et al., 2013; Primec & Belak, 2022).

Legislation and corporate governance play an integral role in the implementation of CSR in companies and information disclosure. Past research suggests that legislation and governance structure influence CSR engagement (Webb, 2004; Jo & Harjoto, 2012) and that the size and independence of the board of directors are often associated positively with sustainability reporting (Kaymak & Bektas, 2017; Cucari et al., 2018). Previous research indicates that legislation impacts the quality of sustainability disclosures. With the implementation of legislation, companies are assigned responsibility for reporting information while also providing key stakeholders with additional information on risks and opportunities for decision-making. Past research shows that countries implementing stricter measures in auditing reported data and financial disclosures would increase transparency and the reporting of disclosed data (Brammer & Pavelin, 2006). In countries where the CSRD and, previously, the NFRD have been implemented, the level of reporting is often higher than in countries where such legislation has not been introduced (Anlesinya & Abugre, 2021; Čufar et al., 2024). Sustainability reporting in the EU has improved over the years with the implementation of the NFRD and later the CSRD. This indicates the impact of sustainability reporting legislation on corporate governance, leading to the gradual integration of sustainability measures within companies' management and governance processes (Čufar et al., 2024).

3 Methodology

The research will be conducted using the multiple case study method. This method was applied to analyze corporate sustainability reporting in practice and to further analyze the impact of legislation on reporting in practice. It was selected because it enables a detailed analysis, understanding, and examination of the studied phenomenon. It allows for the analysis of the phenomenon based on a specific company, which facilitates a better understanding of the subject and the factors influencing it. With this method, it is possible to analyze various aspects using data and analytical approaches. The research analyzed sustainability reports and annual reports (Breijer & Orij, 2022; Maqbool et al., 2022).

For data collection and analysis, the content analysis method was used. The content analysis method has previously been applied in similar studies. This method is suitable for this type of research because it allows for the comparison and examination of qualitative data obtained from sustainability reports of selected companies. The selected method is suitable for the present analysis because it allows for the examination of qualitative reporting by companies and its interpretation. The sample on which the research was conducted includes nine companies from Slovenia, Germany, and France operating in the sectors of insurance. The analysis was conducted based on the annual report or a separate sustainability report published by the selected business entities for the chosen reporting year (Breijer & Orij, 2022; Krippendorff, 1989; Shieh & Shannon, 2005).

The study examined the level at which companies report sustainability information following CSRD requirements. For the study, a research model was developed based on the requirements of the NFRD, CSRD, and ESRS.

4 Results

The research results showed how companies reported in various areas. Based on these results, it can be concluded that the level of reporting was highest for social information, followed by governance information and, afterward, environmental information. In the environmental area, companies reported information related to climate change, pollution, water and marine resources, biodiversity and ecosystems, and circular economy. In these areas, companies reported on more than half of the

requirements set by the CSRD. The most detailed disclosures were related to climate change, followed by pollution, water and marine resources, biodiversity, and circular economy. In the social area, companies achieved the highest level of reporting on information related to their workforce, followed by reporting on stakeholders and employees within the supply chain, local communities, and information related to customers and end consumers. On average, the analyzed companies reported more than half of the required social information following the CSRD. At the management level, companies, on average, achieved the highest level of reporting by disclosing information about the business model and sustainability strategies of enterprises. This was followed by data on the management board and supervisory board, followed by information on managing business partners, internal risk management, and fair business practices.

Based on the research results, companies reported on average more than half of the information required by the CSRD across all three examined areas: environmental, social, and governance. However, these disclosures were not always comprehensive, and many companies did not report on all factors and criteria prescribed by the CSRD. Nevertheless, the results indicate a clear trend toward sustainability reporting and a more comprehensive overview of corporate management from a sustainability perspective.

5 Discussion

Based on the research results, it is evident that companies report data required by the CSRD in their annual reports and sustainability reports. It can be observed that greater emphasis is placed on factors within the social domain, particularly concerning their own workforce and supply chain due diligence. This was followed by reporting at the governance level where companies primarily disclosed information about their business model concerning sustainability, as well as strategies and plans for sustainable development and management. A high level of reporting was also observed in disclosures related to the management and supervisory boards of companies. In the environmental domain, companies achieved the highest level of reporting in the areas of pollution and climate change. The research results indicate that companies are committed to and progressing toward full compliance with CSRD reporting requirements.

The research results also indicate that companies do not report all the information required by the CSRD. Consequently, the findings suggest that there is still significant room for improvement and more comprehensive reporting. Enhancing reporting would not only increase the scope of disclosed information but also better integrate sustainability into corporate governance and management processes. Previous studies have demonstrated that legislation on sustainability reporting influences the disclosure of information by companies in practice (Čufar et al., 2024). Due to regulatory changes in this direction, sustainability reporting has improved over time, showing that legislation has had a positive impact on sustainability reporting in practice.

With the EU proposal and Omnibus regulation, the question arises as to the future direction of sustainability reporting and sustainable corporate governance in practice. Due to the reduction of reporting requirements and the increase in the reporting threshold for companies, it is expected that the level of sustainability reporting may decline slightly or may not progress as significantly as in previous years. Legislative measures serve as incentives for companies to comply with sustainability measures and report sustainability-related information. However, with the relaxation of such measures and a more lenient reporting framework, the question arises as to how this will impact sustainability in practice. On one hand, it is expected that companies will experience greater flexibility due to more lenient reporting requirements. On the other hand, there is a risk that, as a result of reduced reporting obligations and voluntary reporting, companies may not implement sustainability measures proactively within their management and governance processes but instead limit them to the minimum required level. In the long run, this would likely mean gradually moving away from achieving the sustainability goals set by the EU.

6 Conclusions

Based on the research results, it is evident that in practice, companies report information as required by the CSRD legislation. Such legislative measures impact sustainability within companies positively and contribute to the pursuit of the EU's sustainability goals. This represents a significant step toward a circular economy and sustainable management of companies, ensuring that, in the long run, businesses operate efficiently without causing harm or exploiting their environment or other

stakeholders. With the evolution of the economy and global trends, the Omnibus regulation proposal has been introduced at the EU level. This proposal would soften the sustainability reporting requirements set by the CSRD and narrow the scope of companies subject to mandatory reporting. If such legislation is implemented, many open questions and areas of uncertainty will arise regarding the future development of sustainability within companies. Nevertheless, these open questions present an open opportunity for future research. In future research, it would be recommended to analyze the level of sustainability reporting after the potential adoption of the Omnibus regulation and compare it with the sustainability reporting results under the existing NFRD and CSRD frameworks.

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Bridging Traditional and Digital Industrial Symbiosis: Comparative Insights From Croatia and Slovenia in the ESG and Digital Transformation Era

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In the era of ESG and AI, industrial symbiosis (IS) represents a key strategy for achieving sustainable management. This paper presents a comparative analysis of two national approaches, Croatia's traditional, material-based IS model and Slovenia's digitally supported e-Simbioza platform, to explore how analogue and digital pathways can both contribute to ESG goals. Through qualitative analysis of secondary data and case studies, the research highlights how digitalization, including the use of ICT and potential applications of AI, can enhance symbiotic networks through improved coordination, transparency, and predictive analytics. While Croatia demonstrates strong industry-led practices, Slovenia's approach emphasizes digital facilitation. The findings reveal a complementary relationship between traditional and digital models of IS, suggesting that AI and digital tools can gradually augment established IS practices. Despite regulatory and infrastructural barriers, this study offers insights for policymakers and businesses aiming to scale circular economy practices in the context of the green transition and digital transformation.

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1 Introduction

Industrialization and urbanization have significantly increased carbon dioxide emissions and require solutions that balance economic growth and environmental sustainability. Industrial symbiosis has proven to be an effective strategy as it enables companies to exchange materials, energy, water and by-products, thereby reducing waste, lowering emissions and optimizing resource use. Recognized by the European Commission as a key component of the circular economy, industrial symbiosis supports both economic and environmental sustainability.

In Croatia and Slovenia, industrial symbiosis plays a crucial role in promoting Environmental, Social, and Governance (ESG) objectives by integrating environmental innovation into industrial processes. This paper examines how cross-industry collaboration promotes sustainable economic models and strengthens regional resilience. This paper explores how industrial symbiosis contributes to ESG-oriented sustainability through two distinct approaches: a traditional material-exchange model (Croatia) and a digitally enhanced coordination model (Slovenia). The central research question is: "How do different models of industrial symbiosis, one analogue and one digital, support the achievement of ESG goals and what lessons can be drawn from their comparison?"

The paper is structured as follows: The first chapter of this paper is the introduction. The second chapter provides an overview of the relevant literature on industrial symbiosis and its ESG implications. The third chapter outlines the research methodology, data sources, and analytical approaches. The fourth chapter presents the findings, focusing on case studies from Croatia and Slovenia, while the fifth and the sixth chapter discuss the key findings, challenges, and potential solutions. The conclusion summarizes the research contributions and suggests directions for future studies.

2 Theoretical Background / Literature review

A system of production and consumption known as the circular economy (CE) encourages the long-term use of products, boosts resource efficiency, and decreases waste (Erceg et al., 2024). In contrast to the linear model (produce, use, throw away), CE promotes recycling, repairing, and reusing materials in order to reduce the

consumption of natural resources and the negative impact on the environment. CE is applied in various sectors including consumer goods, electronics and textiles, and is based on five models: 1) circular supply, 2) resource recovery, 3) product life extension, 4) sharing, and 5) product service models.

As Erceg et al. (2024) state, the collaboration between industrial businesses, when waste or by-products from one company become raw materials for another, is known as industrial symbiosis (IS), which is a subset of industrial ecology (IE). This model improves resource efficiency, decreases waste, and generates financial gains. In order for companies to reduce the costs of raw materials and waste disposal, companies located close to each other work together in IS and exchange resources (materials, energy, water). The most important goals of IS include increasing competitiveness, extending the life of materials in the economic cycle, and maximizing the use of natural resources. The "3–2 heuristic" is often used to distinguish IS from other types of exchange where at least three entities and at least two types of resources are involved in the exchange (Chertow, 2000).

The most common definition of industrial symbiosis (IS) comes from Chertow (2000), who describes it as the collaboration of traditionally separate entities through the physical exchange of materials, energy, water and by-products, where cooperation and synergy, often enabled by geographical proximity, are key elements (Erceg et al., 2024; Martin, 2020). Lombardi & Laybourn (2020) have proposed a more recent definition of IS, which has been adopted by the Journal of Industrial Ecology. The same definition is summarized by Eomenech et al. (2019), stating that IS is a systematic approach to a more sustainable industrial system that identifies business opportunities through the use of unused resources (materials, energy, water, capacity, know-how, etc.). IS involves organizations from different sectors exchanging resources for the reuse of waste and by-products in order to optimize the value of remaining materials in production processes (Castiglione, 2021).

Industrial symbiosis (IS) involves cooperation between industrial companies through the exchange of materials, energy, water, and by-products, as well as the shared use of services and infrastructure (Van Eetvelde, 2018). An important prerequisite for successful IS is the identification of opportunities for such exchange. The types of resources achieving synergy in the exchange of materials and waste can be raw materials, by-products, waste materials, energy, and water (Erceg et al., 2024).

Figure 1: Examples of Country-Specific Numbers of European Industrial Symbiosis
Source: Erceg et al. (2024)

The best-known example of IS, mentioned by Bilić et al. (2024), Al-Quradaghi et al. (2020), and Gulipac (2016), is the Kalundborg Eco-Industrial Park in Denmark. Kalundborg Symbiosis (see Figure 2) includes both world-leading and smaller companies, but regardless of size, the benefits of industrial symbiosis are clear: cost reduction and lower emissions, growth with fewer resources, more competitive companies, and more resilient societies and businesses.

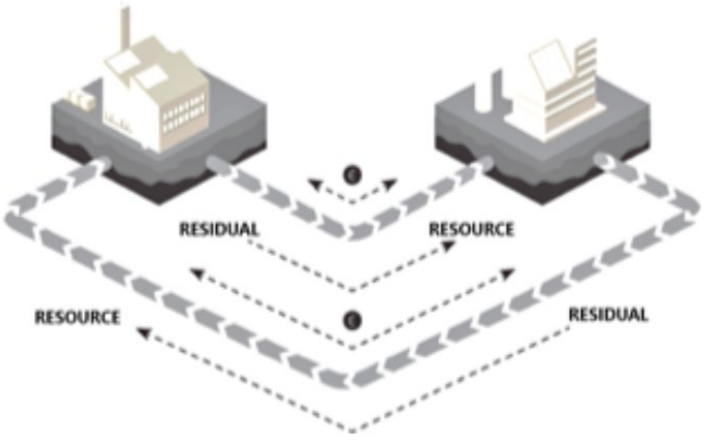

Figure 2: Simplified View of the Kalundborg Symbiosis
Source: Danielsson (2017)

2.1 Industrial symbiosis in Croatia

The model of industrial symbiosis in the Republic of Croatia, illustrated by a concrete example of the use of wood biomass ash (WBA) from power plants in the construction industry (Štirmer et al., 2020), represents a modern form of sustainable management based on the principles of the circular economy. It is a collaboration between the energy sector, which produces WBA as a by-product, and the construction sector, which uses this waste as a substitute raw material in the production of concrete. In this way, the ash, which would otherwise end up in landfill sites and cause environmental pollution, is converted into a valuable resource. From an economic point of view, this model of industrial symbiosis has numerous advantages. On the one hand, power plants save money by not having to pay for waste disposal, while the construction sector saves money by not needing costly primary raw materials like natural sand. On the other hand, new prospects enhance the creation of inventive and eco-friendly building materials, increasing the competitiveness of the home sector. Industrial symbiosis encourages the development of new market niches, boosts local employment, and aids in regional growth. Furthermore, as is the case with the project to create new construction products using PDBs, these models make it easier to secure money from national grants and European funds meant for sustainable development initiatives. The implementation of industrial symbiosis improves resource utilization efficiency while lowering environmental and regulatory expenses. The Republic of Croatia's long-term sustainable development is based on this model, which not only helps the EU achieve its environmental protection and renewable energy goals, but also demonstrates how cross-sectoral cooperation can produce tangible economic and environmental benefits.

2.2 Industrial symbiosis in Slovenia

In Slovenia, urban strategies are being used to explore the potential of industrial and urban symbiosis. Momirski et al. (2021) highlight issues such as a lack of regulations, inadequate waste-to-energy conversion, and low by-product reuse. However, there are chances for better waste management and brownfield redevelopment. The two most crucial elements are greater awareness and the alignment of laws with EU regulations. According to Momirski et al. (2021), industrial symbiosis in Slovenia is an integrated model of collaboration between various industrial sectors and urban

areas that permits more economical resource use and a smaller ecological footprint. This model turns waste, water, energy, and by-products from one production process into valuable inputs for other processes inside linked organizations. This directly supports the objectives of circular economy by reducing the need for new raw materials and creating closed material flows. The creation of the *e-Simbioza* digital platform, which connects various businesses to share resource information, is one of the most significant instances of industrial symbiosis in Slovenia. This platform provides a useful tool for symbiosis implementation at the territorial and industrial zone levels.

From an economic point of view, this model has a number of advantages. Firstly, it makes it possible to reduce companies' operating costs, as the use of by-products or waste as raw materials reduces expenditure on the purchase of primary resources. Secondly, industrial symbiosis increases the competitiveness of companies as it enables them to develop innovative products and business solutions that meet market demand for sustainable practices. Thirdly, companies will have the opportunity to access funding from European and national funds that promote green transitions and sustainable projects. In addition, new space is created for the development of business models based on reuse, remanufacturing, and recycling, which further strengthens the economy's resilience to resource and energy crises. Ultimately, industrial symbiosis in Slovenia not only contributes to sustainability and the reduction of environmental impact, but also creates economic added value through more rational management of resources and new development opportunities for entrepreneurship.

3 Methodology

This paper uses a qualitative methodology based on a descriptive and comparative analysis of secondary data. The aim is to analyse and compare industrial symbiosis models in Croatia and Slovenia in the context of sustainable management, with a particular focus on ESG principles and the concept of circular economy.

The analysis is based on scientific articles, official EU documents, national reports, and case studies, including the application of wood biomass ash in Croatia and the development of the *e-Simbioza* digital platform in Slovenia. A comparative approach was used to explore similarities and differences in institutional, technical, and

regulatory aspects while analysing potentials and challenges, especially in the application of digital technologies to optimize resource flows and connect industrial enterprises. The research question is: How can industrial symbiosis, supported by digital tools, contribute to the achievement of ESG goals in the industry of Croatia and Slovenia? The application of digitalization was analysed qualitatively, as its role in industrial symbiosis is still at an early stage of development and the available data is mostly descriptive and conceptual, which makes quantitative analysis difficult.

Limitations of secondary analysis include the inconsistent methodological approaches of sources, limited access to internal company data, and the possibility that the latest trends and innovations are not yet adequately documented. Despite these challenges, the qualitative approach enabled a deeper understanding of digitalization in industrial symbioses, the identification of key barriers and opportunities, and laid the groundwork for future empirical research that could include quantitative methods and primary data.

4 Results

The research results show that industrial symbiosis is an effective tool for achieving the goals of sustainable management within the framework of ESG in Croatia and Slovenia. Although the two case studies from this paper represent different national and sectoral contexts, they illustrate complementary stages of IS evolution. The Croatian case, on the one hand, exemplifies a conventional, material-based industrial symbiosis model in which industries work directly together to reuse resources. The Slovenian case, on the other hand, is a prime example of the shift to a more digitally integrated model, where ICT support allows symbiotic exchanges to be mapped and activated through platforms like *e-Simbioza*. This distinction is consistent with recent research that acknowledges the digitization of IS as a step in the direction of more intelligent and adaptable symbiotic systems (Lombardi & Laybourn, 2012; Domenech et al., 2019). These cases offer insights into how digital tools can gradually improve traditional IS models rather than reflecting disjointed efforts. Successful industrial symbiosis practices are already in place in both countries, according to an analysis of theoretical sources, industry practices, and case studies. The use of wood biomass ash (PDB) as a substitute raw material in the production of concrete in Croatia highlights the synergy between the energy sector and the construction industry, which has both economic and environmental benefits. One

notable outcome in Slovenia is the digital platform *e-Simbioza*, which links industrial businesses and makes it possible to find possible symbiotic partnerships. Through the reduction of waste, CO_2 emissions, and primary resource consumption, the promotion of local production and employment, and the enhancement of resource management efficiency and transparency through digital tools and technologies, industrial symbioses directly contribute to ESG goals. Digitalization and the application of digital solutions increasingly contribute to the optimization of IS models and enable improved resource coordination, predictive analytics and real-time decision making. Economic benefits include lower operating costs, the development of new market niches for green products and access to funding from EU funds and national sustainable development programs. However, implementation challenges have also been identified, such as a lack of standardized procedures and regulations, limited awareness and knowledge in the industry, and technical and infrastructural barriers, especially for smaller companies.

5 Discussion

This research confirms that industrial symbiosis (IS) plays a key role in achieving ESG goals, with a particular focus on digital technologies as tools to increase efficiency and operational integration of symbiotic models.

From an environmental perspective, IS enables the reduction of waste, emissions, and the consumption of primary resources through the reuse of by-products, energy, and water. The example of the use of ash from wood biomass in the Croatian construction industry confirms the environmental value of IS by reducing the need for primary raw materials.

From a social point of view, IS stimulates employment, strengthens local production chains and enables the revitalization of industrial areas, which is particularly evident in Slovenian urban strategies. Linking different sectors such as energy, construction, and utilities opens up new opportunities for cooperation and sustainable development.

From an administrative perspective, the information society contributes to more transparent and efficient resource management. Digital platforms, such as the Slovenian e-Symbiosis, facilitate the identification and exchange of resources

between companies, improving compliance with ESG requirements and EU regulations.

The role of digitalization further strengthens IS models and enables predictive analytics, logistics optimization and the identification of hidden synergies. Digital systems can support sustainable decision-making and the development of intelligent symbiotic networks that will automate and customize the exchange of resources.

Although IS brings numerous benefits, the main challenges include the lack of regulatory requirements, the low level of digital maturity of companies, limited awareness of the benefits of IS, and resistance to changing business models. Slovenia shows greater institutional support through strategic documents and digital tools.

This comparative perspective reveals that industrial symbiosis evolves along a continuum—from physical, analogue interactions between companies, as seen in Croatia, to more digitally enabled frameworks, as exemplified by Slovenia. While digital platforms do not replace traditional IS models, they enhance them by facilitating faster identification of synergies and enabling data-driven decision-making. Thus, the integration of ICT and AI in IS practices should be viewed as a means of strengthening and scaling up existing symbiotic relationships.

It can be concluded that industrial symbiosis, supported by digital solutions, has significant potential to achieve ESG goals, but requires an interdisciplinary approach, strong political will and active collaboration between industry, regulators, and academia.

6 Conclusions

The paper concludes that industrial symbiosis in Croatia and Slovenia contributes significantly to ESG goals by enabling the reduction of waste, emissions, and business costs. In Croatia, industrial symbiosis practices are industry-led, while Slovenia focuses on digital platforms such as e-Symbioza. Artificial intelligence (AI) has the potential to optimize resource flow and decision-making, but its application in industrial symbiosis is still limited due to a lack of regulatory support, standardized procedures, and awareness in the industry.

The main limitations include the lack of primary data and the variability of methodological approaches in the available literature, making quantitative analysis difficult.

Future research should focus on empirical verification of the role of AI in industrial symbioses and comparative analysis with other EU countries to identify best practices and enable wider adoption of sustainable industrial models.

These findings provide a practical contribution to understanding how sustainable management practices can be enhanced in the age of ESG and AI, aligning with broader European green transition goals.

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THE IMPACT OF INTELLIGENT PROCESS AUTOMATION ON AUDIT AND ON JUNIOR AUDITOR'S SKILLS

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Intelligent Process Automation (IPA) has emerged as a transformative force, building on the foundation laid by earlier robotic process automation (RPA) systems. IPA uses advanced technologies such as artificial intelligence, machine learning and cognitive computing to automate more complex processes that are beyond the capabilities of RPA. Implementing IPA requires detailed strategies and training programs for selected employees who will be responsible for this technology. Nevertheless, this does not fully address the fundamental concerns that are causing possible resistance in the audit industry. The dilemma is whether the integration of IPA into day-to-day audit tasks diminishes the professional value and expertise of junior auditors and newcomers to the field. Automation limits junior auditors' exposure to core auditing tasks, leading to skill and experience gaps in risk assessment, data analysis and analytical insights. This dissatisfaction may lead some junior auditors to leave the profession for roles that offer greater skill development and opportunities for professional growth.

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1 Introduction

Robotic process automation (RPA) emerged as a significant assistive tool in the business sphere in 2012, with its potential to automate rules-based processes that were previously performed manually (that is a simple definition of RPA). The RPA was primarily designed to automate repetitive, rule-based tasks such as data extraction, data entry, and transaction processing. RPA aims to improve operational efficiency by reducing manual effort, minimizing human error, and speeding up task completion (Huang & Vasarhelyi, 2019). By mimicking human interactions with digital systems, RPA enabled businesses to streamline workflows, improve accuracy, and reallocate human resources to more strategic, value-added activities (Gotthardt, Koivulaakso, Paksoy, Saramo, Martikainen & Lehner, 2020). However, RPA developments went beyond their original scope, resulting in the birth of Intelligent Process Automation (IPA). IPA uses advanced technologies such as artificial intelligence (AI), machine learning and cognitive computing to automate more complex processes that were previously beyond the capabilities of traditional RPA (Nunes, Leite & Pedrosa, 2020). RPA is a component of IPA and is used for repetitive activities, whereas IPA is utilized for complicated end-to-end workflows. RPA is rules-based, meaning it uses human-set rules to do activities such as email answering. IPA, on the other hand, combines AI technology, enabling it to handle jobs requiring judgment and analysis without human interaction. It can handle errors and constantly learn from data patterns to enhance efficiency. RPA can only process structured data, but IPA can handle unstructured data (Vanner, 2021).

Advances in technology, especially in the area of process automation, have contributed significantly to the evolution of the corporate world. These technological advances have enabled organizations to increase their productivity and efficiency, resulting in increased profitability and competitive advantage (Gotthardt, Koivulaakso, Paksoy, Saramo, Martikainen & Lehner, 2020). Among these advances, IPA has emerged as a transformative force. The innovative services offered by IPA are cognitive data processing, automated decision-making, process orchestration, etc. (Zhang, 2019). Thus, as a successor (IPA) to its predecessor (RPA), IPA is beneficial for companies. Auditors' analyses and reporting procedures are predominantly based on historical data, specifically financial records and transactions from the preceding business year. Given the substantial volume of data that must be processed throughout the audit process, there is a significant delay in

the timeliness of reporting. This lag can impede the ability to identify risks and inefficiencies in a proactive manner (Lombardi, Bloch & Vasarhelyi, 2014). To address these challenges, IPA plays a crucial role by enhancing data processing efficiency, improving accuracy, and enabling real-time analysis. By integrating automation with advanced analytics, IPA facilitates a more responsive and dynamic auditing process, thereby mitigating the limitations associated with traditional methods (Zhang, 2019). That is why sustainable management that focuses on balancing economic growth, environmental responsibility, and social well-being is needed to ensure long-term success. Such sustainable management is offered by artificial intelligence, which is a key part of the IPA toolkit (Mendelsohn, 2024). Organisation's sustainable management practice must provide employees with an answer to the following dilemma: on the one hand, employees are expected to adapt to this technological transition; on the other hand, they may face certain consequences, including potential dismissal. But what if they adapt? Do they risk becoming devalued as workers, which will eventually turn them into becoming a technical surplus in a society where technology increasingly replaces human roles, or will it make them a necessary asset of the organisation because only they can manage that advanced type of technology? Therefore, the research question for this paper is: Will the integration of IPA into day-to-day audit operations diminish the professional value and expertise of junior auditors and newcomers to the field? In our paper, we use an analytical approach as we analyse previous studies by other authors in search of an answer to our research question. We briefly highlight some concepts that are key to understanding the content of the IPA and auditing.

This paper aims to provide a comprehensive overview of IPA in relation to auditing and auditors. It examines the key contributions of IPA. Furthermore, the analysis delves into the potential challenges and constraints that businesses may encounter in implementing IPA. We discuss the issues related to the use of IPA in auditing and its impact on the workforce.

2 A brief literature review

IPA is the use of several technologies to automate larger, end-to-end business processes. It is the extension of simple, rules-based task automation to the management and automation of complete business processes comprised of several tasks. At its foundation, IPA combines RPA, AI, and machine learning to automate

bigger decision-based business processes that previously required an individual to intervene and execute (Kospompoulos, 2021). IPA mimics human behaviours and, with time, learns to do them even better. Advances in deep learning and cognitive technologies have enhanced traditional rule-based automation mechanisms with decision-making capabilities (Berruti, 2017).

One of the biggest reasons why organizations are warming to IPA is its combination of AI and RPA. Additionally, the benefits it offers are far more advanced than either the use of RPA or AI alone. The results of such a unique combination are as follows. (1) By incorporating advanced technologies such as machine learning and AI, IPA can handle more complex and cognitive tasks that RPA cannot. This enables businesses to automate a broader range of processes, resulting in deeper cost reductions across multiple operational areas (Kospompoulos, 2021). (2) By leveraging AI, IPA systems can learn from data, make decisions, and even predict outcomes, reducing errors and inconsistencies in process outputs (Polner, Wright, Schaefer & Thopalli, 2022). (3) IPA enhances efficiency by automating both routine and complex processes, streamlining workflows across various departments (Kospompoulos, 2021). (4) By automating a wider range of tasks, IPA enables employees to focus less on routine, repetitive activities and more on high-value, strategic projects (Polner, Wright, Schaefer & Thopalli, 2022).

The benefits that many different industries have experienced are the following: the automation of 50-70% of tasks translating into 25-35% annual run-rate cost efficiencies; a 50-60% reduction in straight-through process time; and return on investments in the triple-digit percentages (Kospompoulos, 2021).

While IPA offers a range of transformative benefits to the business landscape, these advantages come with their own set of challenges. The following outlines some of the most critical challenges organizations encounter as they strive to harness the full capabilities of IPA (Hardware Secrets, n.d.):

1. Integration with legacy systems. The term "legacy systems" describes outdated technology that businesses continue to use for essential operations. It is difficult and takes careful planning to integrate IPA into existing systems. In order to minimize disruptions and maximize the benefits of automation, particularly for organizations with older

technologies and established processes, IPA tools and existing software must communicate seamlessly.

2. Data security and compliance. Data security is complicated and involves discussions about government regulation, law enforcement's access to data, and what data businesses may gather. Strong security measures are required to guard against any breaches or illegal access.
3. Employee resistance. Presenting IPA employee opposition to automation may stem from concerns about job instability. Companies could address these issues by communicating clearly, implementing training programs, and stressing that technology complements human skills rather than takes their place.

Addressing this type of challenges is complex and requires a nuanced approach. Simply implementing communication strategies or training programs for selected employees does not fully resolve the underlying concerns that drive resistance. Employees often express apprehension and uncertainty due to a fundamental fear that IPA may render their roles redundant. This concern is compounded by a perception that company leadership views IPA primarily as a means to reduce operational costs, potentially through workforce reductions (Szwed, 2023).

3 Auditing workforce

Junior auditors are entry-level employees who are essential to the auditing and accounting industries. They often assist in a variety of auditing tasks in auditing firms while working under the direction of senior auditors. Their efforts are seen to be crucial in order to guarantee that audit procedures are comprehensive and meet the necessary requirements (Chan, n.d.). They are usually in charge of carrying out the preliminary audit procedures, which involve obtaining and assessing financial data, verifying the correctness of documents, and making sure that pertinent pronouncements are being followed. This practical work is essential for spotting anomalies and possible risk areas. They often evaluate financial accounts and do substantial testing as part of their daily tasks. These tasks need a systematic approach to problem-solving and acute attention to detail (AccountingInsights Team, 2024).

According to projections by the U.S. Bureau of Labor Statistics, employment for accountants and auditors is expected to increase by 4% between 2022 and 2032, potentially creating 126,500 job vacancies per year. However, jobs involving repetitive duties, like data entry and bookkeeping, might decline by more than 20% (Thomson Reuters's team, n.d.). On the other hand, a significant challenge currently faced by audit firms is the shortage of skilled professionals, with vacancy rates reaching as high as 58% (Thomson Reuters's team, n.d.). The other challenge faced by audit firms is recruiting new auditors, which is up by 27%. The dynamic regulatory environment requires continuous adaptation and upskilling, placing additional burdens on both aspiring and existing auditors. This complexity further exacerbates the shortage of qualified professionals in the field, making it increasingly difficult for firms to attract and retain new talent (Thomson Reuters's team, n.d.). Another problem for audit firms is also a low 41% employee retention rate. One of the key factors impacting recruitment is the integration of new technologies into existing work systems, accounting for 27% of the challenges firms face when hiring new audit professionals. Adopting advanced digital tools and automation requires auditors to develop new technical skills, further complicating the hiring process by requiring technological skills and limiting the pool of qualified candidates available to meet industry demands (Thomson Reuters's team, n.d.).

AI in auditing is extensively utilized for data extraction and entry, enhancing efficiency in the collection and input of large volumes of information. Additionally, automated reporting has emerged. AI can generate reports with minimal human intervention, thereby improving accuracy and reducing the time required for manual report preparation (Thomson Reuters's team, n.d.). AI also plays a crucial role in identifying anomalies and irregularities, thereby enhancing the accuracy of audits by detecting unusual patterns in financial transactions. Furthermore, AI is widely employed for analytical insights, facilitating data-driven decision-making in audit practices. Predictive analytics enables auditors to forecast trends based on historical data (Thomson Reuters's team, n.d.). The integration of AI in audit functions underscores its potential to enhance efficiency, accuracy, and risk management capabilities (Thomson Reuters's team, n.d.).

4 Discussion

Integrating process automation in audit practices presents both opportunities and concerns regarding the roles of junior auditors and new entrants to the field. While automation offers efficiencies by handling repetitive tasks, such as data entry and simple reconciliations, it shifts the skill requirements for junior auditors, making adaptability and analytical skills essential to their roles (AccountingInsights Team, 2024). This trend encourages junior auditors to focus on high-value tasks, such as critical analysis and strategic insights, rather than routine checks, ultimately enhancing their expertise in complex areas of the field.

One of the major reasons why audit firms are facing a shortage of new junior auditors is the implementation of newer technology. In addition to the many advantages that we mentioned above from IPA as a tool that it offers to companies, we cannot ignore the fact that it also replaces human power and causes additional challenges and risks for companies.

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 just following it up to see if it is going in the right direction in order to ensure that the organization is effectively adopted and integrated. All of these changes in the organization have implications for employees, i.e. the workforce (O'Sullivan, Raymeent, O'Shannassy & Boland, 2016).

The implementation of IPA can result in a gradual loss of process knowledge among employees, i.e. forgetting the steps of performing an audit. As automated systems take over repetitive, rule-based tasks, human auditors and financial professionals can become less engaged in the detailed execution of these processes. Over time, this can lead to a decline in their understanding of the underlying workflows, dependencies, and decision-making criteria involved in audit procedures. Furthermore, the implementation of IPA can introduce significant control and security challenges if not managed properly. One of the primary security concerns is

that IPA bots often require privileged access to systems and databases to perform their tasks (Eulerich, Waddoups, Wagener & Wood, (2024).

Given all of the potential advantages that the IPA tool itself offers as well as the difficulties that audit firms already have when putting IPA into practice, it is clear that the instrument presents difficulties for both novices and junior auditors. There is a clear danger that it may limit entry-level professionals' access to practical training. Junior auditors have historically developed their skills through manual procedures that call for critical thinking, problem-solving, and a thorough comprehension of financial data. Since IPA manages a large portion of the everyday work, new auditors would not have as many opportunities to hone their core competencies, which might impair their capacity to evaluate intricate transactions, spot anomalies, and utilize professional judgment. This may eventually hinder their ability to advance in their profession as they do not have the breadth of knowledge required to take on more complex auditing duties. However, IPA also provides chances to improve some skills, like junior auditors may concentrate on more analytical, strategic, and value-added responsibilities, including analyzing data trends. Organizations must take a balanced stance to guarantee that IPA integration does not reduce junior auditors' professional worth. Automation initiatives should be supported by mentorship, structured training programs, and active participation in challenging audit tasks.

Based on our brief analysis, we, therefore, believe that the implementation of IPA or any other advanced technologies gradually jeopardizes the auditing industry, particularly by slowly contributing to the development of a workforce with a limited skillset in basic auditing tasks that are usually repetitive but enable junior auditors' growth in skills and experience. The use of IPA in auditing (i.e. in day-to-day operations) is encouraged, but junior auditors must acquire basic knowledge, skills, and experience in auditing. Sole reliance on IPA in auditing is questionable and should be further elaborated.

5 Conclusion

Overall, automation is reshaping the learning landscape for junior auditors by limiting their exposure to core tasks and hands-on practice. As a result, junior auditors may experience skill gaps in data management, risk assessment, and analytical insights—areas critical to their advancement in the field. We are of the

opinion that the value of future auditors is gradually diminishing due to the increased use of technology in auditing (i.e. IPA). Their lack of practical knowledge and reduced practical experience can contribute to dissatisfaction, leading some junior auditors to leave the profession in search of roles that provide greater opportunities for skill development and professional growth.

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Corporate Social Responsibility in the Digital Era: The Role of Emotions in Business Decision-Making and Operational Processes

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Technological development in recent years – increasingly focused on computer science – has seen innovative solutions based on Artificial Intelligence (AI) and the Internet of Things (IoT) pervade every aspect of human knowledge. In the economic sphere, the need to include digital technologies in business processes has led to a radical change in the way companies operate, introducing a whole range of tools that can redefine their decision-making and organizational models. From the perspective of sustainability – a central theme for today's enterprises – the advent of digital would seem to have led to significant benefits, through the optimal use of resources and constant monitoring of production activities and operational processes. However, while environmental and economic sustainability seem to be favoured by the automation of processes, the sense of inclusiveness of the human resources involved in the enterprise is increasingly diminished due to a progressive 'de-empowerment' of stakeholders with respect to decision-making dynamics. Using the Viable Systems Approach (vSa), our paper sets out to analyse the criticalities introduced by digital technology with respect to Corporate Social Responsibility (CSR) and to investigate the role of emotions within decision-making and operational processes, highlighting how a human-centred approach is essential for the sustainable development of modern companies.

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1 Introduction

The issue of sustainability has been, for years now, a top priority for companies in every sector. Growing concerns about climate change and rapid technological progress have, in fact, reaffirmed the central role of social responsibility and environmental impact in strategies for implementing sound and sustainable business models.

If, on the one hand, the advent of digital technologies – Artificial Intelligence (AI) and the Internet of Things (IoT), above all – has introduced a whole series of innovative tools capable of improving efficiency through the automation of processes, on the other hand, it has forced companies to radically reorganise their management models and operational processes, with the aim of including intelligent systems in business dynamics.

Although technological advancement – offering opportunities for innovation, efficiency and competitiveness – has historically been an engine of growth for businesses, it is evident how the integration of digital innovations brings with it challenges linked to a physiological aversion to change – especially when so rapid – and a common sense of distrust towards AI. The latter stems from the thought – easily shared – that the implementation of fully automated strategies could exclude the human being from processes, limiting the role of intuition, emotions and social responsibility in decision-making dynamics (Bassano, 2024).

The objective of companies is, therefore, to try to reconcile economic growth with social equity and environmental protection in the context just described, which sees the entry of new variables into the system and, inevitably, the emergence of new challenges. To all the obstacles to sustainability that traditionally plagued businesses before the advent of digital technologies – e.g. the intensive exploitation of natural resources and the protection of workers' rights – further difficulties are added, related to new issues – data security and the impact of automation, above all.

The phenomenon of stakeholder de-empowerment – that is, the alienation of humans with respect to business processes – is the main negative effect of the digitisation of enterprises. Even though it is now perceived as a particularly worrying reality – especially within companies, where different stakeholders see their decision-

making impact increasingly compromised – the literature in this field seems to focus exclusively on the operational advantages offered by AI, without considering the side effects. Recent studies, in fact, have shown that among companies that have implemented cutting-edge digital solutions, only a small fraction declare themselves concerned about the progressive reduction of human involvement in strategic decisions (Paniccia, 2018).

Starting from the highlighted issues, this paper proposes to analyse – using the Viable Systems Approach (aSv) – the role that the emotional state plays in decision-making processes, in the light of the digital transformation underway. The aim is to legitimise the importance of emotional contribution with respect to automated processes, which equally require active human-centred management. The focus of the research is on the aspects of sustainability that deal with the involvement of different stakeholders in company operational processes, at whatever level. The key aspect to be analysed is, therefore, the impact of digitisation on Corporate Social Responsibility (CSR), with the aim of understanding how an emotionally aware approach can still be essential for sustainable business management in the digital age.

2 Theoretical Background

2.1 The complexity of business operational processes

The role of business decision-making and operational processes has been profoundly analysed in scientific literature. Studies on the subject, in fact, highlight how the optimisation of business processes is the key to achieving planned objectives and creating value (Calabrese et al., 2024). Closely linked to these is the deployment of resources and, therefore, of the skills and competences instrumental to the generation and affirmation of a company's competitive advantage: only if the various operational phases are managed appropriately will the results obtained be consistent with the set objectives (Calabrese et Al, 2024).

This premise highlights how the presence of a decision-making body – capable of selecting the most appropriate strategies according to specific operational contexts – is crucial for companies in any sector, both in the analysis phase of 'as-is' processes and in the subsequent implementation of new ones. What we wish to convey here is that decision-making mechanisms underpin the proper functioning of the

enterprise in all its operational processes and, as such, are indispensable even in a fully automated business environment.

What makes it particularly difficult to imagine separating the dynamics of business decision-making from the role of the human being is the concept of complexity, which is intrinsically connected to both our nature and that of businesses – and the processes characterising them. According to Daft, in fact, the complexity of processes is linked to the degree of interconnection between the resources involved and the different tasks envisaged: in other words, as will be better discussed below, it is a mirror of the systemic relationship between internal stakeholders and the external environment. From this perspective, the connectivity between the parties can be facilitated and supported by digital technologies, but the human decision-making role remains irreplaceable (Daft, 2005).

The goal of sustainable enterprises in the digital age should be, in essence, to be able to adequately reconcile the connection between technological and human resources, fostering an operating environment in which the digital workforce is employed in the production of value by exploiting the shrewd choices made by the human counterpart.

2.2 The role of emotions in the digital age

The human resources involved in operational flows play a fundamental role in the functioning of processes and the determination of their results. Skills, motivations and emotions directly influence organisational performance (Barbagallo, 2012). In particular, the emotional component of human resources deputed to making decisions can be a determining factor in strategic and operational choices: for example, positive emotions can broaden the perspective of decision-makers in making a choice; on the other hand, negative emotions can – even unconsciously – lead to more conservative choices (Damasio, 1994).

Reasoning outside the corporate context, it can be said that the emotional component has, therefore, a correlation with the outcomes of processes – easily found in everyday experience – and is intrinsically linked to their complexity. The emotional aspect, in fact, is undeniably the main element characterising the

complexity of human nature, even before that of business processes – of which the human actor is in any case an indispensable part.

Well before the overbearing advent of digital, emotional intelligence had on several occasions been identified as a tool for dealing with business dynamics, facilitating conflict resolution between operational actors and improving internal collaboration. Several studies have, in fact, shown that the presence of leaders with high emotional intelligence within organisations was the key to improved performance (Goleman, 1998).

With the digital transition of businesses, the way business processes are managed is undergoing a transformation. The complexity of the dynamics is reduced or amplified depending on the ability of companies to adapt the new tools to their existing processes (Barile, 2023). Several studies have shown that without an adequate human-machine combination within processes, digital transformation projects can fail and contribute to an increase in complexity, rather than a reduction of it (Brown, 2019). In this perspective, the emotional elements of the people involved in organisations represent that essential component for the success of digital strategies, which aim at maximising the performance of organisations (Williams & Davis, 2020).

The real challenge for management – especially from the perspective of CSR aimed at the well-being of internal human resources and customer relations – is, therefore, to embrace technology without imposing constraints on the creative and emotional expression of decision-makers.

3 Methodology

3.1 Viable Systems Approach and Corporate Social Responsibility

CSR is a business model encouraging companies to integrate social and environmental concerns into their business operations and decision-making dynamics. In the context of sustainable process management, CSR focuses on the needs of stakeholders – both internal (employees, managers, owners) and external (customers, suppliers, society) – with an eye towards community engagement.

A cutting-edge CSR strategy cannot therefore avoid implementing practices aimed at protecting workers not only from a legal and ethical point of view, but also with respect to their decision-making role within the company, their responsibility and their right to take an active part in decision-making processes. Furthermore, a company's ability to extend its empathetic approach to the public can positively influence consumers' perception of the brand, improve employee satisfaction and well-being, and ensure that the management of processes is guided by ethical principles.

In any case, the link between digitisation and CSR – by virtue of what was said above – cannot disregard the role that emotions play in corporate decision-making processes: the advent of AI, while in some ways favouring sustainable practices, risks detaching companies from fundamental human values. Emotions thus become a key factor in maintaining a balance between technological progress and social responsibility, as they represent the link between innovation and the well-being – based on trust and a sense of belonging – of stakeholders.

The relationship of coexistence of the human element (decision-maker) and the technological element (implementer) in business processes can be explained in a straightforward manner by taking up some fundamental concepts of aSv. The structure/system dichotomy, for example, allows us to understand the crucial role of operational processes in the life cycle of the enterprise: it is precisely these that dynamically make a system – aimed at a specific objective – emerge from a 'static' structure (Barile, 2009). It is as if the will to pursue a purpose enables the relationships between resources, bringing out the internal capabilities (general patterns) and specific competences (specific patterns) necessary for the creation of value (Calabrese et Al., 2024).

In other words, there is a relationship between technological/digital structure and human resources, which is realised in processes. These play a key role in the combination of resources and their integration within the organisation, in order to achieve 'organisational consonance' between the parties (Barile, 2008). Going back to the concept of the relevant supra-system, it is as if the strategic directions traced by the decision-making processes allowed the enterprise, in its systemic wholeness, to adapt – asserting its competitive advantage – to the external context in which it operates (Sciarelli, 1999). In this way, the 'enterprise system' – through its internal

operational processes – manages to establish a consonant relationship with its supra-systems, ensuring its survival.

3.2 The role of emotions in decision making dynamics

The relationship of interaction between viable systems and their supra-systems – both in the context of business management and in everyday human relations – is described by one of the fundamental principles of aSv, that of 'isotropy' (Barile S., 2023). According to this principle, the system is called upon – whenever its equilibrium is disturbed by the occurrence of a problem – to make choices that allow it to modify itself, readjusting to its relevant supra-systems. This modification takes place on the basis of decision-making patterns, derived from value categories – the set of strong believes that characterises every viable system from birth – which represent the filter through which each individual acquires new information.

Translated into a business perspective, the role of the decision-making body within companies is to ensure that the principle of isotropy is respected through a series of choices that readjust strategies and reorganise processes according to the needs – from inside or outside – of the system itself. It follows from what has just been said that business processes are strongly linked to the value categories of the decision-makers, since the choices of the latter directly determine the adaptation of the processes themselves to the various operational contexts of reference. According to this perspective, the digital transition represents a need that the various 'company systems' could not pursue without the action of one or more human decision-makers capable of rearranging the pre-existing structure through their decisions (Lerner, 2015).

Once we are convinced of the inalienability of the human role in business management – whether traditional or digitised – we need to discuss how the emotionality that characterises each individual intervenes in the determination of choices. The role of value categories in this regard is well formalised by the Information Variety Model (IVM):

$$V_{inf}(k) = f[U_{inf}(k), S_{int}(k), C_{val}(k)],$$

according to which the information variety (V_{inf}) – i.e. the mental conformation of the decision maker at the moment of choice – of a given system 'k' is a function of the value categories (C_{val}) of the decision maker, of the interpretative schemes (S_{int}) derived from them and of the information units (U_{inf}) available to the system (Barile S., 2023).

Observing the mathematical formalisation of the IVM, the aSv would appear to give no weight to the role of emotions in decision-making processes; however, the fact that emotions do not appear explicitly in the writing of the information variety function does not prevent us from believing – as found in everyday experience – that a causal principle nevertheless exists between them and the choices made by the life system. This principle can easily be traced back to the relationship between emotions and value categories, represented by a kind of dynamic interweaving, whereby – in a cyclical sense – values influence our emotionality and emotions, for their part, accompany value categories in their process of defining interpretative schemes.

4 Discussion

What has just been analysed – through the interpretative tools offered by the aSv – suggests how emotionality has a significant weight in decision-making dynamics by virtue of its direct link with the value categories that characterise human beings. The genesis of emotions, if you like, is in some way linked to the vicissitudes introduced by contextual dynamics, which is why they – even more so than the value categories themselves, which on the contrary do not take context into account – are able to influence the decisions that lead to the construction of individual processes. To summarise, emotions represent the direct effect of applying interpretative schemes – derived from value categories – to the boundary conditions introduced by the context (Barile S., 2023).

The fact that the literature on the subject concentrates a great deal on the technological aspect of business processes, while paying very little attention to the role of emotions in decision-making and operational processes – be they internal (managerial) or external (consumer relations) – is a clear sign of a lack of understanding of the concepts just outlined. Such a shortcoming prevents one from appreciating the 'emotional' nature of business processes, not allowing one to

correctly interpret the role of the human being and his intrinsic complexity in business management. The complexity of business processes is, in fact, often assessed by resorting to the measurement of quantitative parameters – such as inter-connectivity within workflows and operational efficiency – that do not consider the emotional response of decision-makers - both in the planning phase and in the execution of processes.

Nevertheless, it is indeed difficult – referring once again to one's own observational spirit – to think of ignoring the effect of the emotional state on the choices we are called upon to make in everyday life. Referring to the 'company as a viable system', therefore, it is even more complicated to think of describing and assessing the efficiency of processes based exclusively on criteria not considering the decision-maker's emotional equipment or – even worse – to hypothesise a future in which the role of the human decision-maker is replaced by digital technologies.

Having clarified the importance of emotions in the choice phase of the life system, the question remains as to what effect this has on individual operational processes – that is, how emotional action affects the complexity of processes. Reinterpreting Goleman's thought from an aSv perspective, the emotions of the human resources involved in business processes can contribute to the reduction of process complexity or its amplification, to the same extent that context dynamics influence the variation in the system's level of consonance with its supra-systems (Goleman, 1998; Barile S., 2023).

In short, the emotional state of the decision maker at the time of the choice represents the level of openness (or consonance) of the system with respect to the strategies to be implemented and influences – positively or negatively – the complexity of the processes and the speed with which they are modified. From this, it follows that strategic and operational planning cannot disregard the human factor and emotional elements, having to adequately value the impact they can have on the information variety and performance of organisations.

5 Conclusions

The focus on the structural elements of processes – and, in particular, the digital technologies that support them – increasingly directs scholars in the field toward a biased view of interpretative models of business systems. Such a view focuses on

efficiency, connectivity and technological integration, often conceiving the human factor as an exclusively structural element and ignoring, as a result, any emotional contribution that human resources can release in terms of expanding the variety of information useful for decision-making and operational processes. From the perspective of sustainable business development and CSR – based above all on the well-being and full awareness of their role by corporate resources – it is important that, even at a time when digital transition is now a categorical imperative, the importance of human value is not forgotten. Through the lens of aSv, this study highlights the indispensable role of human emotionality in decision-making dynamics and their action on the complexity of operational processes with a view to corporate sustainability. The paper highlights how for companies of the future, it is critical to develop strategies that balance AI and emotional intelligence to ensure a sustainable human-centered growth model.

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An Analysis of the Social and Linguistic Construction of Artificial Intelligence

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The purpose of this research is to highlight the important role that language and discourse play in the business world with regard to shaping society. We want to show that the way we use language to communicate can have a significant impact on societal development. We start from the premise that language is a central tool in the construction of social reality, and therefore the discourse used by companies plays a key role in shaping perceptions and values. Given the rise of AI across various domains, our exploration focuses specifically on the economic discourse within the so-called "fourth revolution" – the AI revolution. Throughout the paper, we hope to stimulate the interest of researchers from different disciplines to pay attention to the often overlooked category of language.

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1 Introduction

Language is, despite its importance, often overlooked in research outside the linguistic disciplines. This lack of attention is precisely what we wish to address in this article. Focusing on language and economic discourse, we can define language as a "social construction, which allows communication between members within a social group, and connects separate groups into a unified whole" (Pogorelec, 2024, p. 75). Even so its effects as a social construct can be hard to quantify, particularly because language use is frequently considered trivial. This is perhaps most applicable to speech itself which in the context of conversation often serves the purpose of talk, "simply for the sake of talking itself" (Eggins & Slade, 1997; p. 6 in Young, 2004, p. 15). We should be careful however, not to conflate the triviality of the act of talking with the triviality of the language used. This is because "speech conveys much more than the words that talker chooses to utter" (Hagoort, 2019, p. 24).

So why does language play such an important role in our social lives and how can this approach be used to help us expand our understanding of the influence that Artificial Intelligence (AI) has on our society? In response, we aim to provide an overview of potential research avenues at the intersection of artificial intelligence and sociolinguistic studies.

2 Theoretical background / literature review

Language is not a rigid structure but like all social constructs, it is shaped by the specific time and place in which it is used. As explained by Pogorelec (2024, p. 59) "communicating, understanding, responding in a common language develops over time and changes slowly." This change is still bound and curtailed in some ways. Most prominently, we can turn to the uniformitarian principle (Labov 1994, in De Busser, 2015, p. 133), from which "we can suppose that language structures in the past were subject to the same constraints as language structures now in the present."

"Because language is as a social and, therefore, also a historical creation – a heritage that is passed on, altered and supplemented from generation to generation – it is the responsibility of all of us who speak it, write it and thus pass it on." (Pogorelec, 2024, p. 59) Adding to this, Gumperz & Levinson (1996, p. 1 in De Busser, 2015, p. 1)

state: "culture, through language, affects the way we think, especially perhaps our classification of the experienced world."

It could even be argued that this relationship can be inverted, as "most of our culture clearly depends on the human ability to communicate ideas and construct artifacts with the help of natural language" (Hagoort, 2019, p. 1). Pogorelc (2024, p. 59) expands on this, stating that "language enables thought /…/ therefore, thinking is not possible without it." The influence of language on culture construction is also incredibly subtle, as "speakers very often aren't even aware of the linguistic phenomena and characteristics of their speech" (Bitenc, Stabej in Žejn, 2021, p. 36).

In this way, the relationship between language and culture can be seen as serving a very specific function: maintaining types of thought that support existing power structures, or as stated by Howlett & Raglon (2001, p. 246 in Fill and Mühlhäusler): "/T/he ideological legitimation of social relations is embedded in the structures and discourses of each and every society and extend from the largest to the smallest social relations and institutions."

Language is a complex phenomenon, its use and form affected by multiple variables. On an institutional level, it is affected by "social structure and the general organization of society" – things which, as stated by De Busser (2015, p. 13), are "typically outside the conscious control of individual members of that society" – along with "cultural factors, which are the result of beliefs and ritualized behaviors" (De Busser, 2015, p. 13).

As proposed by van Dijk (1997, p. 2), we can constrain the understanding of discourses to three main dimensions: the use of specific forms of language, the communication of beliefs, and the interaction in social situations. It is especially important to address language in the sphere of economics. This is because language is both influenced by and consequently constructs economics as a field (De Busser, 2015, p. 13-14 in Weinrich, 2001, p. 91-92).

As stated by Grimm (1819 in Fill and Mühlhäusler, 2001, p. 91): "Language is economical everywhere. It employs minute inconspicuous means and nevertheless achieves great ends." From common expressions to turns of phrase, economic language constantly informs our understanding of the world. As stated by Weinrich

(2001, p. 92 in Fill and Mühlhäusler): "Anyone who prefers a full purse to an empty one will agree that a language that is rich in words is preferable to one that is poor in words."

This is significant when we consider the dominating effect of language and its relationship to power. Domination is not enacted only through direct action, but also "through our habits of language as well, encoded linguistic biases of which we are often unaware" (Kahn, 2001, p. 241). This plays an important role in enshrining structural power (Machin & Mayr, 2012), through "linguistic strategies which diffuse ethical questioning and maintain the ideologies and agendas of those in power" (Kahn, 2001, pg. 243 in Fill and Mühlhäusler).

This is especially relevant in the sphere of economics, including in fields such as green advertising (Howlett & Raglon, 2001, p. 245-253 in Fill and Mühlhäusler), where companies aim to "create corporate images which are environmentally friendly or benign" (Howlett & Raglon, 2001, p. 245 in in Fill and Mühlhäusler). Another strategy pointed out by Bloor & Bloor (2007, p. 107) is topic control, which encompasses "control over turn-taking and hence over the content of discussion."

Looking at Fairhurst & Putnam (2004, in Allen, Walker & Brady, 2012), we can identify a specific approach to organizations as discursive formations that can prove to be very helpful in our understanding. As Allen, Walker, & Brady (2012) elaborate, this is the grounded-in-action orientation, one in which the organization and discourse are separate forces that both influence each other.

We have already touched on some aspects of critical linguistics, particularly in exploring "how language and grammar can be used as ideological instruments" (Machin & Mayr, 2012). Expanding on this, Machin & Mayr (2012) explain that "humans do not live in an objective world, but rather that this world is shaped for them by the language that has become the medium of expression in their society."

Corporations can play a vital role in the construction of the language used to create this world and often find benefit in 'adjusting' the discourse to fit their needs (Howlett & Raglon, 2001, p. 245-253 in Fill & Mühlhäusler), and none are perhaps more predisposed to do so than corporations involved in technological development. As Bloor & Bloor (2007, p. 139) elaborate: "When discussing major

changes in society in the past half-century or so, there is a tendency to emphasize technological progress, particularly in the fields of computing and communications," continuing later, in relation to the rapid growth of commercialization, that "this is closely bound up with the technological advances which have extended and improved the channels and modes of discourse, /…/ providing not only improved means for accessing markets but also new products to sell there."

Artificial intelligence (AI) is increasingly entering the discussion as the catalyst of a fourth industrial revolution (Forstnerič-Hajnšek, 2023; Nemorin, Vlachidis, Ayerakwa & Andriotis, 2023, p. 38). As Rakowski & Kowaliková (2024, p. 2) elaborate, "we are currently living in a time of digital transformation often referred to as digital turn or rise of artificial intelligence." It is undeniable that "the number of tools based on artificial intelligence (AI) designed to assist human decisions has increased in many professional fields" (Vicente & Matute, 2023).

In recent times, we have seen a staunch rise in the use of AI technologies inside the labor market (Liu, Chen & Lyu, 2024), with the technology quickly proving itself to be the "driving force behind a new technological revolution" (Liu, Chen & Lyu, 2024, p. 2).

Artificial intelligence has proven especially impactful, as it affects not only the field of industry but also exerts powerful and immediate consequences for society at large (Rakowski & Kowaliková, 2024). However, this also means, that "the integration of technology, AI, people and data presents new ethical and political challenges and dilemmas in its implementation" (Rakowski & Kowaliková, 2024, p. 2).

For this reason, it is imperative to understand what AI is, and what people perceive it to be. On that point, AI has redefined the very way that consumers act within the marketplace (Jain & Kumar, 2024). As Brewer, Bingaman, Paintsil, Wilson & Dawson (2022, p. 560) explain, there are three domains in which people's perceptions of AI are influenced: "news coverage, science fiction, and interpersonal discussion" – all rooted in communication. In general, "people are more likely to talk about AI /…/ when they communicate with others" (Dong, Jiang, Li, Chen, Gan, Xia & Qin, 2024). These all provide certain 'frames', through which AI can be understood. While the word is not directly stated, we can still draw a connection

between these and the construction of different discourses – ways of describing AI that prescribe it with different meanings.

In general, most of the language surrounding AI can be categorized into two broad, opposing discourses: one where AI is seen as a progressive force that improves society (Engster & Moore, 2020; Ferràs-Hernández, Nylund & Brem, 2023; Shen & Zhang, 2024; Zhang & Peng, 2024), and one where AI is framed as a dysfunctional force, often a detriment to social progress (He, 2024; Kieslich, Keller & Starke, 2022; Yi, Goenka & Pandelaere, 2024).

Let us tackle the first of the two discourses. Concerning the pro-AI position, a few sub-discourses arise. The first and most obvious is the conception of AI as a new technology (Shen & Zhang, 2024). The focus here is placed specifically on the innovative aspect of AI, and especially on its ability to 'think'. Personalization of large language models can also be seen as part of this discourse, as they are ascribed with a certain level of sentience (Gomes, Lopes & Nogueira, 2025).

Perhaps the most common approach, particularly in the economic sphere, is AI as a tool for greater economic productivity (Ferràs-Hernández, Nylund & Brem, 2023; Shen & Zhang, 2024; Zhang & Peng, 2024). As Engster & Moore (2020, p. 202) put it: "Artificial intelligence (AI) is being touted as a new wave of machinic processing and productive potential." As Shen & Zhang (2024, p. 5) add, AI is a useful tool for economic growth as it "reduces the demand for coded jobs in enterprises while increasing the demand for nonprogrammed complex labour, /…/ deepened and refined the division of labour, /…/ advanced productive forces, /…/ improving their job satisfaction and employment quality, /and/ reduces the distance between countries in both time and space, promotes the transnational flow of production factors, and deepens the international division of labour."

On the opposite side of the spectrum, an aspect of the anti-AI discourse that is worth going over, though it seldom sees mention within the economic sphere is the environmental cost of AI (Delort, Riou & Srivastava, 2023; Kieslich, Keller & Starke, 2022, p. 2). Here, emphasis is often placed on AI as a drain on resources, rather than a resource saving tool, centering not on AI's capabilities, but on the material expenses required for its operation.

Lastly, we can mention AI's cultural homogenization (Ferrara, 2023; He, 2024; Singh & Ramakrishnan, 2023; Yi, Goenka & Pandelaere, 2024). This discourse concerns several spheres, from culture to religion and emphasizes the influence of power and norms on AI as a product of societal forces (Ferrara, 2023) and how biased preconceptions can lead to bias within AI. He (2024, pp. 2-3), for example, focuses on religion and stresses that AI can provide a stifling effect that devalues traditional and religious beliefs. Additionally, it has been shown that "biased recommendations made by AI systems can adversely impact human decisions in professional fields such as healthcare" (Vicente & Matute, 2023).

3 Discussion and conclusions

As we have already outlined throughout this paper, to some authors, AI appears to be the herald of the fourth industrial revolution. Whether this is true remains to be seen, but one thing is certain: through AI we can observe an expansion of the power of the economic sphere. If AI is to be at the spearhead of the fourth wave of industrial development, then its ability to pierce into nearly every domain of social existence, to play a role, however slight, in everything from culture to art to menial labor, means that its power is near guaranteed.

So, if AI is the herald of a new age, what can we say about the discourses surrounding it? As we have outlined, there is a dualism in understanding, a divergence within the discourse, creating two diametrically opposed constructions that are, nonetheless, similar in their focus on AI's power and it near-universal influence. The pro-AI discourse promotes AI both as a technological and economic achievement capable of revolutionizing nearly every field of study, work, or leisure. However, the anti-AI discourse also emphasizes this all-encompassing nature, framing AI not as a force of liberation and revolution, but as one of control and stagnation, through discourses focusing on repression and homogenization and its destructive potential through ecological discourses.

A significant obstacle to this research can be found in the clear lack of writing on the subject of discourses and language use relating to Artificial Intelligence. Most of the existing material on AI looks at it from a materialist perspective, focusing on AI's transformative potential for economic growth or the dangers of its power consumption. Perhaps the closest are critiques of AI as a tool that entrenches power

relations. Put more simply, most writing about AI is very much still concerned with its effects, while not really delving into what AI is, or what people see it to be. This is perhaps unsurprising – AI is itself quite a modern phenomenon – but that leaves a largely unexplored field of study, a field that can expand our understanding of AI in a different direction than the equally valuable research concerned with AI's effect.

Lastly it is worthwhile to touch upon the fact that language is extremely specific, with structures and use cases varying wildly even among related languages. As Hagoort (2019, p. 21) tells us, "In order to use language, people must learn the specific ways in which their language expresses meaning and recruit this knowledge when expressing the meanings they wish to convey or when retrieving those of others." In practice, this means we must be especially mindful of ascribing broad cross-cultural meanings to concepts and should refrain from the simple adoption of foreign discourses, as there are great differences in the way that different languages and, consequently, different cultures construct and think of seemingly similar concepts.

These are still undoubtedly useful, as with the growing interconnectedness of the world, some discursive elements are bound to overlap, but they should serve to inform research, not substitute it, since substitution would result in less precise explanations and a poorer understanding of AI. This is doubly true for small languages such as Slovenian, which constantly adopt many meanings and important phrases from more dominant languages. From this perspective, it becomes even more important to analyze language use within these smaller languages because this higher level of melding can cause us to better understand how meaning is transferred and adapted between languages.

A significant limitation also emerges from this cultural specificity, as most linguistic analysis – limited as it already is – is also focused largely on western European languages. Therefore, the understandings that have been produced in this field tend to stem from these languages, which then often become the basis for discourse in other language groups as well. For this reason, from a more socially conscious standpoint, more attention should be directed towards the study of language relating to AI, specifically within smaller languages, in order to attempt to preserve their cultural autonomy in whatever way possible.

It is important to mention that there are also certain aspects of the discourse which were omitted from this paper simply due to the lack of both relevant materials and expertise, given the multidisciplinary nature of AI-related issues. In this respect, we encourage further study from different fields – from cultural to judicial – to expand our understanding of the subject.

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PUBLIC-PRIVATE PARTNERSHIPS FOR GREEN SKILLS: EVALUATION OF DIFFERENT STAKEHOLDERS UNDER THE SHADOW OF GAME THEORY MODEL

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Green skills development is central to achieving sustainability goals, but development of green skills is hindered by strategic triads of governments, private sector players, awareness campaigns, large data intermediary players. The aim of writing this research work is to develop a game theory framework for incentive and strategic decision in where the green skills are absorbed. Initially with a strategic game in which every player decides whether to invest in green skills L or H. Payoff functions have economic benefits, costs, and externalities that will arise because of other players choices. Thus, a Prisoner's Dilemma effects yielding low cooperation (L, L) exogenously, although it is socially optimal to invest, yielding (H, H). A Public Goods Game framework emphasizes the issue of free riding, in which actors receive the benefits of others' contributions without investing themselves. The study analyzes potential policy interventions to address the inefficiencies by exploring the implications of government subsidies (S_G), penalties for non-compliance, and public-private partnerships that help to realign incentives. This research work developed a framework with key green skill components to guide policymakers and businesses to optimize their green skill development strategies. Utilizing insights from game theory, stakeholders can create incentive-compatible mechanisms that ensure collaboration, productivity, and a workforce dedicated to innovation.

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1 Introduction

The path toward a sustainable, low-carbon economy depends critically on the development of green talents. It entails arming people and companies with the knowledge, resources, and skills required to promote environmentally responsible behavior, encourage innovation, and slow down global warming (OECD Cedefop, 2014). Reaching this shift, however, calls for group efforts among several stakeholders—including the government, the business sector, awareness campaigns, data-sharing systems, technological application and innovation. Though their activities are often intertwined and create a complicated ecosystem of cooperation and competition, each of these stakeholders has a vital role to contribute to promote green skills (Peloza & Falkenberg, 2009).

Here, game theory offers a helpful analytical framework for comprehending the strategic interactions among these parties (Pérez-Cirera, 2010). Modeling how these individuals could behave when their individual payoffs are affected by the actions of others. Game theory—a subfield of mathematics that investigates decision-making in circumstances when outcomes depend on the decisions of several agents. It helps applying game theory to green skills development allows us to investigate how various stakeholders might cooperate or free-ride on one other's investments in green projects as well as what systems might support best collaboration.

2 Literature review

How does green skills impact by Government (G) initiatives

Government programs play a crucial role in developing green skills, particularly in developing economies. These programs include green production incentives, environmental sustainability policies, and investments in education that aim to align the workforce's skills with the needs of a green economy. The impact of these programs in addressing the green skills gap continues to be a key research focus. In the Thailand context, the national skill-formation and education system has struggled to produce industry-ready employees with green skills. Napathorn (2022) highlights that universities and vocational colleges are unable to provide students with the appropriate green skills, leading to a shortage of skilled workers. To mitigate this, companies often rely on internal green human resource management (GHRM)

practices, such as on-the-job training and mentorship programs. While these internal initiatives help address the skill gaps, government intervention is essential to integrate green skills into national curricula and training schemes.

Governments can also create industry-academia partnerships. Napathorn (2022) proposes that additional university-industry partnerships would enable additional green knowledge transfer, less dependent on in-company training programs. Agrawal et al. (2023) also posit that government-funded training programs and public-private partnerships can enhance knowledge transfer and employee skill building.

In spite of these interventions, evidence reveals that government interventions are not necessarily enough to trigger mass green skills uptake. Agrawal et al. (2023) identified that government policies create the platform for green practices but have little direct impact in encouraging green skills unless complemented by social awareness campaigns. This suggests that government interventions are successful if they are accompanied by mass involvement in the wider society and education campaigns.

Additionally, other businesses are not ready to embrace green practice because of profitability issues. Agrawal et al. (2023) observe that while some businesses utilize green certification to increase brand value, other businesses consider the investments in sustainability as expensive and are not ready to embrace green technologies unless they are driven by stricter regulations or economic incentives. Governments should, therefore, supplement green skills policy with economic incentives like tax relief and subsidies to motivate businesses to embrace green technologies.

Private Sector Contribution to Green Skills Development

The private sector also has an important role to play in promoting green skills through embedding business strategy and sustainability objectives. Firms have a role to play in enhancing green skills via green human resource management (GHRM), investment in low-carbon technologies, and collaborative arrangements with academic institutions. Effectiveness of the contribution of the private sector is reliant on regulatory systems, fiscal policy incentives, and organizational dedication to sustainability.

Companies increasingly understand that they need to invest in green skills to remain competitive in the changing economy. Napathorn (2022) points out that in Thailand, companies have no choice but to create green skills internally since the national education system is incapable of producing graduates ready for industries. This investment is typically in the form of on-the-job training, mentorship schemes, and partnerships with universities to incorporate sustainability into curricula. Vaquero et al. (2021) also highlight that private sector investments in upskilling workers are essential to improve adaptability to green job standards and to overall economic resilience.

Aside from training, green innovations in the private sector have a critical influence on workforce skill development. The European Green Deal, for example, emphasizes that job creation and specialized green skills are stimulated by private investments in renewable energy, sustainable mobility, and waste prevention. In Spain, businesses have used EU recovery funds to adopt green strategies that reconcile profitability with environmental sustainability, developing a skilled workforce in clean energy and circular economies (Vaquero et al., 2021). There are various challenges that prevent the private sector from scaling green skills development. Vaquero et al. (2021) identify that there are companies that resist green training investments because they have cost concerns as well as uncertainty about the benefits. Furthermore, companies' announced sustainability pledges and actual workplace transformation, there can be a large gap because most green activities tend to be compliance-driven rather than development-oriented. To overcome these issues, increased public-private partnerships and specific incentives must be applied to persuade companies to focus on green skills development.

Effect of Awareness Campaigns on Green Competency Development

Public awareness campaigns are important for developing green competency because they enhance ecological awareness, behavior, and drive people towards adopting sustainable practices. Empirical evidence confirms the notion that awareness campaigns, if complemented by education and training, increase green motivation and ability, which, in turn, contributes to enhanced environmental performance.

Awareness campaigns like environmental education, outreach to communities, and media communication, enable individuals to understand the significance of sustainability and gain key green skills. Yafi et al. (2021) discovered that awareness-based training programs significantly improve the attitudes, knowledge, and skills of workers concerning sustainable practices. Also, properly structured awareness activities trigger spontaneous green actions, like conserving energy and reducing waste.

Green human resource management (GHRM) also incorporates environmental consciousness into organizational training, enhancing green competencies among workers. Yafi et al. (2021) added that individuals who are more environmentally aware are more likely to adopt sustainable workplace behavior. This is why awareness campaigns are important in bridging the knowledge-action gap when it comes to green skills.

Despite their promise, awareness campaigns simply can't drive short-term awareness into long-lasting green behaviors. Yafi et al. (2021) observes that although awareness campaigns may arouse preliminary interest, long-term behavioral change is made possible through training and reward mechanisms. Moreover, socioeconomic status, cultural orientations, and exposure to green education can determine the success of these campaigns in supporting green skill acquisition.

Effect of Data Sharing Platforms on Green Skills Development

Data-sharing platforms between governments and enterprises are central to promoting green skills development. Through the sharing of sustainability-related data, these platforms assist in upskilling workers, enforcing policies, and influencing technology development in the green sector.

Decision-making based on data is increasingly becoming vital in the green economy. Vaquero et al. (2021) highlight that data-sharing platforms between private organizations and government institutions facilitate the development of sophisticated green skills through the real-time access to such crucial metrics as energy efficiency indicators, carbon footprint, and regulatory compliance trends. Such online platforms also enable firms to coordinate their employees' training programs with changing sustainability standards.

In addition, data-sharing activities provide significant data insights on trends in the labor market and greener job prospects. In accord with OECD (2021), data-driven analytics facilitate mapping out the skills demand, thus equipping education and training institutions with the capacity to create programs oriented toward the adaptive needs of environmentally friendly industries. Through data sharing, the provision guarantees workers learn appropriate skills for inclusion in green businesses that are more environmentally friendly.

Though beneficial, data-sharing platforms are confronted with a number of challenges in promoting green skills development efficiently. Vaquero et al. (2021) observe that challenges like weak data governance, fragmentation, security threats, and interoperability among systems hamper the efficiency of the platforms. Moreover, firms will be reluctant to exchange proprietary sustainability information owing to competitive issues, which can impair the efficiency of data-exchange programs in creating green skills.

Effect of Technology Adoption and Innovation on Green Skills Development

Innovation and technology are central to the development of green skills in that they change the demands on the workforce, generate new employment opportunities, and lead to the shift to a sustainable economy. With the development of new green technologies, staff have to develop new competencies, technical skills, and problem-solving skills to meet the challenges of environmental sustainability.

Green technologies, including renewable energy, energy-efficient systems, and smart automation, are changing industries at a fast rate. Nikolajenko al. (2021) point out that transitioning to a greener economy hinge on getting the workforce ready with high-level green skills corresponding to these technological developments. They point out that new green industries need employees with technical, mechanical, and IT-related skills to enable sustainability-oriented sectors.

The International Labour Organization in 2018 estimates that green technological shifts may generate almost 24 million jobs worldwide and displace 6 million jobs in carbon-emitting sectors. This transition highlights the urgency to reskill and upskill employees to remain employable in changing green industries (ILO, 2018).

In spite of the increasing need for green skills, a number of challenges hamper their universal application. Viederytė et al. (2021) observe that new graduates lack the technical competencies necessary for green occupations, especially in areas like renewable energy, sustainable building, and environmental management. In addition, most organizations are unable to integrate green technology training into current workforce development programs because of financial limitations and a lack of institutional support.

3 Results

Green skills framework with multiplayers. In this framework, the model a strategic game involving five players: 1. government (α1)i; 2. private sector (α2)i; 3. awareness initiatives (α3)i; 4. data sharing platforms (α4)i; 5. technology usage & innovation (α5)i. Each player has the option to choose between two strategies:

- High push-initiatives (H): Invest in high green skills aggressively
- Low push-initiatives (L): Low interest in green skills

Strategy mechanism. Each player selects its strategy based on high-low mechanism. Therefore, each player [(α1)(H1,L1), (α2)(H2,L2), (α3)(H3,L3), (α4)(H4,L4), (α5)(H5,L5)]. The collective strategy will be written as, S= (α1+α2+α3+α4+α5).
Payoff Functions. Each player's payoff depends on several factors:

- Economic outcomes thus the gains achieved from the investment in green skills Ei (S)
- Costs appear be to the expenses incurred for implementing green initiatives Ci(S)
- External factors are the positive or negative spillover effects that occur due to the strategies chosen by others thus (any player) EFi (S)

The payoff function can be written as follow for the each player, Ui = Ei (S) - Ci(S)+ EFi (S). Where: Ei (S) is the economic benefits for player (α1…..α5), which increases when more players choose H due to positive network effects (i.e., the more players invest in green skills, the greater the overall benefit). Ci(S) is the costs incurred by player (α1…..α5)„ which are typically higher when H is chosen because implementing green skills is costly. EFi (S)is the externality or spillover effect from

other players' actions. For example, if the government invests in green policies, the private sector might benefit without direct cost (positive externality). In Table 1. shows the Payoff Matrix.

Table 1: Payoff Matrix

Player (Government – Private sector)	**High push-initiatives (H)**	**Low push-initiatives (L)**
High push-initiatives (H)	(Max, Max)	(Min, Max)
Low push-initiatives (L)	(Max, Min)	(Min, Min)

Source: own editing

Where *Max* = 1 … infinity and *Min* = -1 …, 0. *(Max, Max)* means that both the government and private sector invest in green skills. They both benefit equally, thus representing the maximum benefit when both cooperate. (Min, Max) is when the government invests, but the private sector free-rides (does not invest). The government incurs costs, while the private sector benefits from the government's investment. (Max, Min) means that the private sector invests, but the government free-rides. The private sector incurs costs, while the government benefits from the private sector's actions. (Min, Min) is when neither the government nor the private sector invests in green skills, leading to no benefits for either, and stagnation in green skills development.

Application of game theory. Considering the fact, several game theory models fit this framework to examine possible results and strategic interactions.

Prisoner's Dilemma:

A. Dominant Strategy: Low Effort (L)(Min). Players may choose the strategy that reduces their expenses (i.e., free-riding), thereby under investing in green talents, based on the payoff matrix.
B. The Nash Equilibrium happens at (L, L)(Min,Min) where both participants free-ride. Still, this is less than ideal since it results in stagnation in the evolution of green talents.
C. The socially ideal outcome is (H, H)(Max,Max), in which both participants invest to maximize the group payback.
D. Optimal Soluition: To get the best result, rules, incentives, or subsidies could be required to guarantee cooperation.

Public Goods Game:

Green skills and talents are a public benefit; and considering the fact free-riding is a risk. Role of Government: Subsidies (Gs) offered by the government can help the private sector to commit in green technologies. The payback for the private sector, for instance, might be changed as: Ui = Ei (S) - Ci(S)+ (Gs).

Evolutionary game:

Strategies and Techniques may change with time in long run. Early adoption that is, governments or businesses may inspire other participants to follow their approaches and move to High Effort (H) if they find great advantages from funding green technologies. Furthermore, because of positive externalities and economic growth, players that adopt High Effort (H) could gain more over time, hence promoting the dissemination of high-effort techniques.

4 Conclusions

The game theory framework for green skills development considers strategic interactions between key players (government, private sector, awareness initiatives, data sharing platforms, and technology usage). Based on the outcomes we have to take into account the following to reach best cooperation in the development of green skills. Taxes or penalties for participants who do not contribute – that is, companies not using green technologies – are known as penalty for free-riding. Government subsidies to change incentives will help to attract private sector and other actors to invest in green skills. Public-private partnerships allow the public and private sectors to help lower individual expenses and risks, thereby facilitating the investment in green talents. Platforms for data sharing and technology transfer help to lower adoption obstacles and optimize the network impacts of environmental projects. Government initiatives are critical to the development of green skills, with their impact stemming from policies that promote sustainable practices, educational reforms, and industry-academia collaborations. However, the success of these initiatives relies on effective implementation, alignment with industry needs, and collaboration with businesses.

The private sector is an important source of green skill development through green technology investments, training programs, and partnerships with learning institutions. Nevertheless, in order to have maximum impact, corporations need to shift beyond the stage of mere compliance and infuse long-term green skill initiatives into their day-to-day operations. Future research could investigate firm-level barriers to the adoption of green skills and the efficiency of incentive schemes as a means to encouraging private sector investment in sustainable training. Awareness campaigns play a crucial role in promoting the development of green skills through motivation, knowledge, and behavior. Yet, to enhance their effectiveness, awareness campaigns must be supported by formal training programs and organizational support systems. Future studies must investigate the long-term impacts of awareness campaigns on green workforce development in different industries.

Green skills development can be expedited through data-sharing platforms between the business and government by providing greater accessibility to key sustainability data and correlating workforce training with industry demands. To maximize their effectiveness, however, stakeholders need to confront data governance, privacy, and industry collaboration issues. Future research should be targeted at the long-term success of these platforms in green labor market formation and creation of a sustainable economy. Technology adoption and innovation are critical drivers of green skills creation by creating new sectoral demands and job opportunities for sustainable industries. Nonetheless, a seamless transition involves sector-specific training programs, robust industry-academic collaboration, and policy-friendly frameworks. Future studies must aim to assess the potency of technology-driven green training programs in imparting future-tight skills to workers.

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The Evolution of Energy Awareness in Hungary: Examining Consumer Awareness, Attitudes and Individual Responsibility in the Context of the Energy Crisis

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For decades, energy consumption—much like personal finance—was regarded as a low-involvement issue, receiving limited attention from the public. Only recent global disruptions, particularly the energy crisis, have prompted a shift in consumer perceptions. The crisis has underscored the unsustainability of prior consumption habits and exposed the vulnerability of energy systems. In response, an increasing number of consumers are demonstrating interest in energy awareness, sustainable behavior, and the potential of renewable energy sources. Although resistance to renewables remains, this is often rooted in insufficient education and a lack of intergenerational engagement with responsible energy use. In some population segments, energy is still not perceived as a value. This study investigates how the energy crisis has influenced consumer awareness and behavior in Hungary. Specifically, it explores the emergence and levels of energy awareness, the internal (e.g., environmental values, personal responsibility) and external (e.g., financial pressure, informational access) motivators driving behavioral change, and evolving attitudes toward renewable energy. It also examines whether consumers perceive a relationship between energy awareness and the crisis. Furthermore, the study offers recommendations on how artificial intelligence can be utilized to promote energy-conscious behavior through tailored educational interventions and decision-support tools.

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1 Introduction

The promotion of energy-conscious behavior has become a critical imperative in the context of accelerating climate change and increasing energy system vulnerabilities. Although modifying deeply ingrained consumer habits presents considerable challenges, it is essential for achieving long-term sustainability. Effective, accessible communication and education are instrumental in guiding individuals through the complexities of energy use (Hassan et al., 2009). The depletion of fossil fuels, rising greenhouse gas emissions, geopolitical tensions, and volatile energy prices have exposed the fragility of energy infrastructures—conditions that have proven especially acute in Hungary. These developments have rendered previous consumption patterns economically and environmentally unsustainable, particularly for socioeconomically disadvantaged populations. Despite the growing body of literature on sustainable consumption, empirical research remains limited regarding how sudden crises reshape consumer attitudes in Central and Eastern Europe. This study addresses this gap by examining both internal and external motivators of energy-conscious behavior, focusing not only on financial incentives but also on personal responsibility, environmental values, and social influences—and their dynamic interplay. Notably, while this research highlights key drivers of behavior change, it does not extend to the underlying psychological mechanisms, such as emotional responses or cognitive biases, which merit further investigation in future studies.

2 Literature review

Hungarian society is facing pressing challenges shaped by global developments, with climate change, energy production and consumption issues, and energy market instability threatening the sustainability of current economic systems and social behaviors (Kovács et al., 2022). Energy awareness and conservation have become increasingly important not only environmentally but also economically and socially. The adoption of energy-efficient and innovative technologies offers substantial savings for households and businesses, enhances energy security, reduces import dependency, and stabilizes energy prices. Ironically, the recent energy crisis may accelerate the shift towards renewables. Similar to the 1970s oil crisis, the 2021 energy crisis has spurred research into alternative energy, underlining the urgency of

diversification (Gajdzik et al., 2023). The crisis has also shifted consumer attitudes, with more individuals viewing renewables as essential to the future. This study investigates how the crisis has positively influenced energy awareness and consumer behavior (Gârdan et al., 2023). A growing segment of the population has embraced energy-efficient practices, recognizing the need to adjust consumption habits. Fundamental knowledge about energy and renewables is key to fostering an energy-conscious mindset (Meyer et al., 2021). Without reliable information, misinformation may prevail, resulting in apathy or rejection. Energy consciousness is shaped by psychological, sociological, economic, and environmental factors (Mansor et al., 2019) and is mainly achieved by modifying energy-inefficient habits. While sustainability and environmental issues have gained attention, early campaigns had limited influence on personal responsibility. For years, energy was seen merely as a basic necessity. Only after a prolonged process did individuals begin to value energy, adopt responsible consumption, and embrace new behaviors. The energy crisis has further motivated this shift, with socio-economic status, lifestyle, housing conditions, and energy knowledge all affecting how households respond (Slupik et al., 2021; Zhao et al., 2019). Energy awareness fosters conservation, as informed consumers can substantially reduce their usage and influence others (Gadenne et al., 2011). Despite information availability, Hungarian energy awareness remains low, with just 12.5% perceiving the population as energy-conscious. Regional disparities persist, shaped by education, living standards, and socio-economic status (Szakály et al., 2021; Áldorfai et al. 2022). Although some behavior changes have occurred, further willingness to act is crucial for fostering sustainable consumption (Wall et al., 2021).

3 Methodology

This study aimed to examine how the energy crisis has shaped Hungarian consumers' attitudes toward renewable energy, focusing on public perceptions, prior knowledge, levels of awareness, and both internal and external motivations influencing purchasing decisions. Data were collected via an online questionnaire administered through the Surveyplanet platform, structured around four key areas: knowledge of renewable energy, attitudes and preconceptions, user experiences and influencing factors, and demographic background. A stratified random sampling method ensured geographic, age, and gender diversity. The final sample consisted of 400

valid responses, with 54.8% identifying as female and 45.2% as male. Respondents' age distribution was: 18–25 years (6%), 26–35 (18.9%), 36–45 (26.3%), 46–55 (30%), 56–65 (8.3%), and above 65 (4.1%). Most participants (72.8%) were from Budapest or Pest County, while 27.2% represented rural areas across Hungary.

4 Results

The energy crisis and its effects, such as rhapsodically fluctuating prices, have disrupted the daily operations of all energy stakeholders. Therefore, it was deemed essential to examine how participants perceive the impact of the energy crisis as an external event on their interest in and openness towards renewable energy. Moreover, this study aims to determine whether the energy crisis can be considered an influencing factor in the willingness to adopt renewable energy sources, changes in consumer behavior, and the dissemination of an energy-conscious mindset.

- **Consumer openness:** A significant proportion of respondents perceive a growing openness among consumers toward renewable energy solutions. Specifically, 18.7% indicated that the ongoing energy crisis has increased public interest in renewables, whereas only 4.8% believe the crisis has had minimal impact on attitudes. Despite the expanding visibility of environmental movements, the data suggest that environmental protection has not yet achieved widespread behavioral engagement among the general population. Economic factors appear to be a more immediate driver of behavioral change. Approximately 70% of participants reported that rising energy prices prompted them to modify their consumption habits, while 24.4% indicated no notable change in response to these pressures. Furthermore, the dissemination of energy-saving recommendations by utility providers appears to be gaining traction. Respondents demonstrated a heightened receptiveness to such guidance, suggesting a shift from passive awareness toward active information-seeking behavior in relation to energy efficiency.

- **Internal and external consumer motivations:** Beyond the quantitative aspects of energy consumption, consumer behavior has shifted significantly in response to technological change, including the rise of online shopping. These developments have shaped new attitudes, motivations, and risk perceptions.

External factors—such as the Russian-Ukrainian war and the ongoing climate crisis—have intensified public awareness of energy issues, prompting both policy and individual-level reassessment (Rausser et al., 2023). Understanding energy awareness requires examining both internal and external drivers: internal factors include beliefs, habits, and environmental values, while external ones encompass financial pressure and geopolitical instability. This study's findings highlight financial considerations as the primary motivator for adopting renewables—26.8% cited cost reduction, 24.4% rising prices, and 23.2% environmental concerns. Additionally, 13.4% sought energy independence, and 6.1% referred directly to the energy crisis. These results point to a complex interaction between economic reasoning and normative commitments. While cost-efficiency continues to dominate, the growing importance of environmental values suggests the emergence of intrinsic, responsibility-driven motivations. Together, these internal and external factors are fostering a measurable increase in energy-conscious consumer behavior (Smith et al., 2021).

- **Motivational factors behind energy awareness**: The findings of the study reveal a multifaceted set of internal and external factors influencing Hungarian consumers' energy-related decisions and attitudes toward renewable energy adoption. Among the most salient external motivators were financial considerations—reported by 26.8% of respondents—as well as the broader economic impact of rising energy prices. Internally, environmental awareness and normative commitments to sustainability emerged as key drivers. Additionally, motivations such as the pursuit of energy independence and the influence of the ongoing energy crisis were identified as significant contributing factors, reflecting the complexity of behavioral responses under conditions of uncertainty.

- **Financial considerations**: The data indicate a pronounced sensitivity among Hungarian consumers to fluctuations in energy prices, with many expressing a strong preference for financial predictability and security. In the wake of the energy crisis, a distinctly financially conscious consumer segment has emerged—characterized by proactive risk mitigation and long-term planning. For 13.8% of respondents, the adoption of renewable energy technologies is

perceived as a pathway to self-sufficiency and a buffer against future price volatility. However, this group tends to evaluate such investments through a pragmatic lens, emphasizing the importance of a clear and timely return on investment. Their motivation is closely tied to measurable utility savings that can be redirected toward other household expenditures.

- **Rising energy prices**: The energy crisis elicited a range of behavioral responses among consumers, shaped primarily by individual financial circumstances and varying levels of energy awareness (Azizi et al., 2019). This heterogeneity underscores the need to consider socio-economic segmentation when assessing consumer adaptation strategies:

  1. **Price-sensitive consumers**: Many households rapidly implemented energy-saving measures, leading to a significant decrease in overall energy consumption. In certain cases, this entailed substantial adjustments to daily routines and lifestyle patterns (Azizi et al., 2019). When economic conditions allowed, some consumers further responded by investing in renewable energy technologies or energy-efficient systems as a means of long-term adaptation.
  2. **Energy-poor regions**: In response to energy constraints, households in less affluent regions significantly reduced their energy consumption. Where feasible, they supplemented this reduction by increasing their reliance on fossil fuel-based sources to meet essential energy needs (Vágány et al., 2024).
  3. **Information-seekking or educated consumers**: This group actively pursued information on conservation methods, aligning their energy use with financial constraints and implementing diverse strategies to optimize consumption.
  4. **Hedonistic consumers**: Uninfluenced by rising energy costs, this group maintained their usual consumption patterns and comfort levels without making any adjustments to their energy use (Trzęsiok et al., 2019).

- **Environmental awareness and energy crisis**: Even prior to the energy crisis, certain consumers were committed to environmental protection, reducing their ecological footprint, and securing a sustainable future for their children (Jaciow et al., 2022; Radácsi & Szigeti, 2024). Some had already adopted renewable

energy technologies as a proactive measure against climate change, demonstrating both informational engagement and a willingness to invest in green solutions (Ul-Mulk et al., 2018). The crisis further accelerated this shift, enhancing interest in energy independence. According to the data, 12.6% of respondents were directly motivated by the crisis to consider renewables, 18.4% perceived a broader societal shift, and 64.1% held a positive view of public receptiveness. Financial savings often served as a basis for further sustainable investments (Farghali et al., 2023).

- **Responsibility**: Survey findings reveal that respondents view energy-conscious behavior as a collective responsibility, indicating strong public awareness and accountability. While the state is seen as primarily responsible—particularly in advancing renewable energy—energy providers are also expected to support sustainable practices. Individuals with a heightened personal sense of responsibility are more likely to engage in conscious consumption and expect similar efforts from institutional actors, especially in light of the ongoing reliance on fossil fuels (Kollmuss et al., 2002; Imre et al., 2019; Szeberényi et al., 2022).

- **Consumer energy awareness and practices:** While some consumers were already energy-conscious, the energy crisis marked a significant shift, prompting broader recognition of the unsustainability of prevailing consumption habits. Survey data show that 54.6% view the transition to renewables as essential, with respondents rating their energy awareness at an average of 6.65 out of 10. Only 1% reported no engagement in energy-conscious practices. This awareness is evident in behavior: 28.6% use energy-efficient appliances, 32.7% actively track and reduce consumption, and 9.2% utilize renewable energy sources.

- **The role of Artificial Intelligence:** Artificial intelligence (AI) plays an increasingly pivotal role in promoting energy-conscious behavior. Through smart meters, automation, and tailored recommendations, AI enables households to monitor and optimize consumption (Iorgovan, 2024). It also assists in evaluating renewable investments and identifying cost-effective solutions. On a systemic level, AI supports predictive energy management,

enhancing grid efficiency and reducing both costs and environmental impact. By providing data-driven insights, AI fosters deeper energy awareness and sustainable decision-making.

5 Conclusions

The findings of this study confirm that the recent energy crisis has acted as a significant external catalyst in reshaping Hungarian consumer attitudes toward energy use and renewables. Although financial considerations remain the dominant driver of behavioral change, a parallel shift is emerging toward intrinsic motivations such as environmental concern and personal responsibility. This indicates the development of a more complex and layered understanding of energy awareness among consumers. Importantly, the study highlights the role of both internal (e.g., normative values, sustainability awareness) and external (e.g., rising costs, policy signals) motivators, and their interdependence in shaping energy-related behavior. The segmentation of consumer types—ranging from price-sensitive to environmentally committed—underscores the need for differentiated policy and communication strategies. While current energy awareness is largely limited to consumption reduction, it provides a solid foundation for cultivating broader, long-term behavioral change. The findings suggest that enhanced education, tailored information, and digital tools—particularly AI-driven solutions—can play a key role in expanding awareness and fostering active engagement. Although the study offers valuable empirical insights, it does not explore the deeper psychological drivers of energy behavior. Future research should investigate cognitive and affective mechanisms to provide a more comprehensive model of energy-conscious decision-making.

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AI-Powered Cryptocurrencies and Sustainability: The Role of Intelligent Blockchains in Green Technology Development

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The convergence of artificial intelligence (AI) and blockchain is fostering the emergence of AI-powered cryptocurrencies, which offer sustainable alternatives to energy-intensive digital finance systems. This paper examines how AI supports the environmental, social, and governance (ESG) performance of blockchain ecosystems. AI integration enables the use of energy-efficient consensus mechanisms, improves decentralized finance operations, and facilitates ESG compliance. Projects like Render Network, Fetch.ai, and Ocean Protocol illustrate how AI can increase data processing efficiency, minimize redundant computation, and promote carbon-neutral tokenomics. These platforms support smarter asset distribution through decentralized data marketplaces and machine learning applications. The research methodology involves a review of academic literature, analysis of market statistics, and energy consumption data comparison. The results demonstrate that AI-powered cryptocurrencies can achieve significant energy savings—up to 35% compared to centralized systems—and exhibit strong market growth, with their total capitalization rising more than tenfold between 2021 and 2024. The findings suggest that AI-enhanced blockchain technologies play an essential role in advancing sustainability in digital finance. This study provides guidance for regulators, developers, and investors aiming to align blockchain innovation with green technology principles and responsible market practices.

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1 Introduction

The integration of blockchain technology and artificial intelligence (AI) is driving innovation in the digital economy by creating systems that are not only decentralized but also more sustainable. AI-powered cryptocurrencies enable the automation of complex data processes, improve energy efficiency, and support decentralized data marketplaces. These capabilities make them viable alternatives to traditional centralized digital infrastructures, which are often associated with high energy consumption and inefficiency (Kapitonov et al., 2022). Proof-of-Work (PoW)-based cryptocurrencies, such as Bitcoin, have raised serious environmental concerns due to their excessive electricity usage and carbon footprint (Jones et al., 2024). In contrast, emerging AI-supported blockchain solutions leverage alternative consensus mechanisms and intelligent resource allocation to reduce these negative impacts. Projects such as Ocean Protocol and Fetch.ai have shown that decentralized systems powered by AI can enhance computational efficiency and data processing, while also contributing to environmental goals (Aslam et al., 2023). The aim of this study is to explore how AI contributes to the sustainability of blockchain ecosystems, with a focus on improving energy efficiency, optimizing data flow, and supporting compliance with Environmental, Social, and Governance (ESG) standards. The paper positions these technologies within the broader context of sustainable digital transformation (Kumar & Tripathi, 2024).

2 Theoretical background

Blockchain technology relies on decentralized, distributed databases that ensure secure and transparent digital transactions without the need for centralized intermediaries (Nakamoto, 2008). Its cryptographic consensus mechanisms and immutable ledger structure have made it a key innovation in digital trust systems. However, despite these advantages, blockchain—particularly systems operating on Proof-of-Work (PoW) algorithms like Bitcoin—has been widely criticized for its excessive energy demands, as the validation process requires vast amounts of computational power and electricity (Sedlmeir et al., 2020; Sallay & Csiszárik-Kocsir, 2024). While alternative consensus models such as Proof-of-Stake (PoS) have emerged to reduce energy use, they do not fully resolve the broader challenges of sustainable computation, especially as blockchain applications expand beyond finance into areas such as logistics, health care, and smart infrastructure

(Cheikosman & Mulligan, 2023). In this context, recent theoretical and applied developments suggest that artificial intelligence (AI) offers a promising avenue for improving the environmental and operational efficiency of blockchain systems. AI technologies can optimize consensus protocols, predict and allocate computational loads more efficiently, and dynamically manage energy distribution across nodes, thus reducing system-wide consumption. In particular, AI can be used to enhance real-time decision-making in decentralized applications and to facilitate self-adjusting system behavior, allowing blockchain networks to adapt to changing environmental or operational conditions (Xiong et al., 2023). Examples such as Ocean Protocol and Fetch.ai illustrate how decentralized AI-powered data marketplaces reduce duplication, lower storage and transmission needs, and support efficient machine-to-machine communication (CoinMarketCap, 2024). Render Network, by distributing GPU power through a decentralized architecture, enhances rendering efficiency and minimizes energy waste in AI-intensive tasks. The potential of such integrations is increasingly supported by regulatory developments. Frameworks like the European Union's Markets in Crypto-Assets (MiCA) regulation mandate ESG-related disclosures and encourage the adoption of sustainable technologies, pushing blockchain development toward more transparent and accountable operational models (European Union, 2023). The convergence of AI and blockchain is therefore not only technologically feasible but increasingly necessary to align innovation with environmental, regulatory, and societal expectations.

3 Methodology

This study investigates how the integration of artificial intelligence (AI) enhances the sustainability of blockchain-based financial systems. The research methodology is based on a structured combination of qualitative and quantitative approaches, including a systematic literature review, statistical analysis of market data, and energy efficiency comparisons.

First, a structured literature review was conducted using academic databases such as Scopus, Web of Science, IEEE Xplore, and ScienceDirect. We applied a keyword-driven search strategy using terms like "AI-powered cryptocurrencies," "blockchain sustainability," and "ESG compliance," focusing on peer-reviewed English-language articles published between 2018 and early 2024. Based on predefined inclusion

criteria, 41 relevant publications were selected and analyzed for their conceptual and empirical contributions to the integration of AI and blockchain in sustainable digital finance.

Second, we analyzed market data for 18 AI-related cryptocurrencies, selected from CoinMarketCap and CoinGecko under the "AI & Big Data" category. The dataset spanned January 2021 to March 2024 and included daily metrics such as market capitalization, trading volume, and token price. These data were processed in Microsoft Excel using descriptive statistical methods to identify trends in asset growth and sustainability-oriented investor behavior.

Third, energy consumption was assessed by comparing blockchain consensus protocols using data from the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024). The environmental performance of AI-supported platforms such as Ocean Protocol and Render Network was evaluated based on public whitepapers, ESG reports, and third-party energy audits. Additionally, seven institutional reports from global organizations including the IMF and the World Economic Forum were reviewed to contextualize the findings within current ESG and regulatory developments in digital technologies.

4 Results

Empirical observations and market statistics confirm that the integration of artificial intelligence (AI) into blockchain technology has significantly enhanced the sustainability profile of several cryptocurrencies. The development of AI-based cryptocurrencies has accelerated rapidly, especially between 2021 and 2024. According to data from CoinMarketCap (2024) and CoinGecko (2024), the total market capitalization of selected AI-related crypto assets increased from approximately USD 2.7 billion in early 2021 to over USD 39 billion in early 2024. This remarkable growth—more than a 14-fold increase—is visualized in Figure 1, which illustrates the expanding role of AI in blockchain ecosystems.

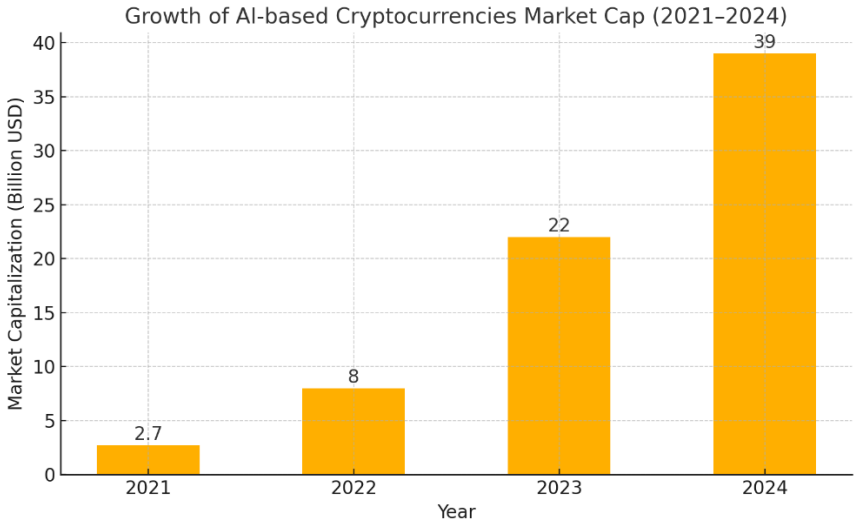

Figure 1: Growth of AI-based Cryptocurrencies Market Cap (2021-2024)
Source: Own edited figure based on data from CoinMarketCap and CoinGecko (2024)

Prominent AI tokens such as Render Token (RNDR) and Fetch.ai (FET) experienced price gains between 200% and 600% during the same period (CoinDesk, 2024). These trends reflect not only the technological appeal of AI integration but also the growing investor demand for blockchain solutions with sustainability-oriented value propositions.

Regarding energy efficiency, the adoption of decentralized, AI-enhanced blockchain platforms has resulted in measurable improvements. Based on data from the Cambridge Bitcoin Electricity Consumption Index (CBECI, 2024), such platforms consume between 25% and 40% less electricity compared to centralized data centers performing similar computational tasks. For instance, Ocean Protocol's decentralized data marketplaces reduce energy usage by up to 30% by minimizing redundant processing and enabling more efficient resource allocation (Xu et al., 2024; Kapitonov et al., 2022). Similarly, Render Network enhances energy efficiency through decentralized GPU resource sharing, further reducing overall consumption.

The potential of these technologies is further reinforced by evolving regulatory requirements. The European Union's Markets in Crypto-Assets (MiCA) regulation, effective from 2024, mandates ESG metric disclosures from cryptocurrency service

providers. This has led to increased publication of sustainability reports by platforms like Ocean Protocol and Fetch.ai, which helps improve transparency and build trust among investors (European Union, 2023; Kumar & Tripathi, 2024).

Broader institutional perspectives also support these findings. Reports from the International Monetary Fund (IMF, 2024) and the World Economic Forum (2023) emphasize the role of AI-embedded blockchain networks in achieving ESG objectives and long-term regulatory alignment. The World Economic Forum, in particular, highlights how AI-based decentralization enhances transparency and facilitates public acceptance of blockchain innovations.

5 Discussion

The findings of this study support the hypothesis that the integration of artificial intelligence (AI) into blockchain systems contributes meaningfully to the sustainability of cryptocurrency technologies. The substantial increase in the market capitalization of AI-based tokens and the growing interest in ESG-aligned financial assets indicate that market participants increasingly prioritize energy-efficient and socially responsible solutions (Peschko & Zölitz, 2025; Kumar & Tripathi, 2024). This trend highlights the strategic importance of embedding sustainability into the design and operation of decentralized financial infrastructures. Projects such as Ocean Protocol, Fetch.ai, and Render Network illustrate the practical advantages of combining AI with blockchain, particularly in terms of improving computational efficiency, minimizing redundant processing, and optimizing the use of distributed resources (Aslam et al., 2023; Xu et al., 2024). These systems significantly reduce energy consumption and carbon emissions when compared to traditional centralized infrastructures, and thus play a leading role in the shift towards green digital ecosystems (Farkas & Kucséber, 2021).

It is essential to recognize, however, that the application of AI technologies within blockchain ecosystems is not without limitations. Although AI significantly contributes to decision-making efficiency and the optimization of resource allocation, its deployment—particularly in machine learning and high-performance computing contexts—requires substantial computational power, which may result in increased energy consumption if not carefully managed. As highlighted in prior studies, the sustainability benefits of AI integration are contingent not only upon its

functionality but also upon the conditions of its implementation. These benefits are maximized when decentralized infrastructures are combined with energy-aware algorithmic design and hardware configurations that prioritize computational efficiency (Kapitonov et al., 2022). Absent such considerations, the introduction of AI may paradoxically exacerbate environmental burdens instead of mitigating them.

At the same time, regulatory developments—most notably the EU's Markets in Crypto-Assets (MiCA) framework—are pushing cryptocurrency developers toward greater transparency and ESG compliance. This evolving regulatory environment presents both opportunities and constraints: it fosters innovation in reporting and energy monitoring, while also raising the bar for compliance and operational standards. The success of AI-powered blockchain platforms will largely depend on their ability to demonstrate measurable sustainability impacts, adapt to regulatory requirements, and maintain technological relevance in an increasingly ESG-focused digital economy (European Union, 2023; Kumar & Tripathi, 2024).

6 Conclusions

This study investigated the extent to which the integration of artificial intelligence (AI) into blockchain technologies can support the development of more sustainable cryptocurrency systems. The analysis confirms that AI-powered blockchain solutions offer measurable benefits in terms of environmental sustainability, particularly through reduced energy consumption, improved resource allocation, and support for compliance with Environmental, Social, and Governance (ESG) frameworks. The substantial growth in the market capitalization of AI-related cryptocurrencies—rising from approximately USD 2.7 billion in early 2021 to over USD 39 billion in 2024—indicates that investors increasingly value platforms that combine technological innovation with sustainability objectives (CoinGecko, 2024; CoinMarketCap, 2024). Moreover, decentralized infrastructures that incorporate AI have demonstrated up to 35% greater energy efficiency than their centralized counterparts, resulting in lower overall electricity usage and a reduced environmental footprint (Kapitonov et al., 2022). These developments are closely aligned with regulatory trends, such as the European Union's MiCA regulation, which mandates ESG disclosures for crypto service providers and encourages the adoption of greener practices across the industry (European Union, 2023; Kumar & Tripathi, 2024). In light of these findings, it can be concluded that AI-supported blockchain

systems have the potential to play a key role in the transition to a more sustainable digital economy. Their continued advancement may not only contribute to climate goals and energy reduction efforts but also provide new opportunities for regulatory alignment, economic value creation, and technological competitiveness in a rapidly evolving global financial landscape.

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The Role of Artificial Intelligence and Electronic Intrusion Detection Systems in Protecting Solar Power Plants

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The aim of the study is to show how the integration of artificial intelligence (AI) and electronic intrusion detection systems can contribute to increasing the security of solar power plants. The study analyses the use of smart camera systems, motion sensors, infrasound sensors and drone technology. The operation, benefits and integration potential of each technology are evaluated. The results show that AI-based systems significantly reduce false alarms, enable faster response and increase the effectiveness of security systems. Automated intrusion detection and drone-based surveillance facilitate proactive protection. The effectiveness of these systems can be affected by external environmental factors such as weather conditions, sensor maintenance requirements and the deployment of technological infrastructure. In addition, the use of AI may raise privacy and legal issues that need to be taken into account in its practical implementation. The results will contribute to safety engineering improvements and provide practical guidance for solar plant operators. AI-based systems create the potential for adaptive, self-improving security mechanisms that reduce human resource requirements and increase the reliability of security systems. The novelty of the research lies in the combined use of AI and electronic security, which allows for more effective operation of object protection systems.

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1 Introduction

Artificial intelligence is playing an increasingly important role in various industries, including critical steps for efficient operation of companies, or the defence systems of solar power plants (Pap et al., 2024). Due to their technology, solar power plants are located in areas that require increased security attention. The majority of these areas are located in so-called brown zones on the edge of residential areas. The surroundings of solar panels located on the edge of residential areas are typically very busy, with little pedestrian or vehicular traffic. And solar arrays on the outskirts are located in outlying areas where the barren environment poses a safety risk. There is no movement of people, goods or people during the operation of the solar power plants, except for maintenance, and therefore they are not subject to vigorous protection. In this situation, intrusion detection and monitoring systems supported by artificial intelligence play a key role. AI-based surveillance systems can autonomously detect suspicious movements, analyse their behavioural patterns and reduce false alarms. AI-powered systems support decision making by processing data in real time, allowing the centre to respond to alerts faster and more efficiently (Fogarasi & Kovács, 2020).

2 Operation and main elements of solar power plants

2.1 Operating principle

Solar PV systems with an electrical capacity of over 500 kVA are classified as solar PV power plants. The solar panels produce direct current (DC) from sunlight, which is first converted into alternating current (AC) by inverters in the strings. The string collection stations and the transformers at the node then "step up" and "feed in" the current, which is already 120 kV AC, to the national grid voltage level. The biggest difference compared to other solar systems - which is also important for protection - is the size. Such power plants can cover several hectares of land and have fences that can be hundreds of metres long.

2.2 Spatial distribution of a solar power plant

The solar power plant is divided into four areas based on their functions (Table 1).

Table 1: Spatial layout of the solar power plant

environment	boundary	buildings	assets
– **industrial and dirt roads**	– fencing	– inverter (1000 V DV - 400 V AC) + sub-transformer (0,4/6 kV AC) buildings	– power converters – solar panels – support structure
– **hiking and tourist paths**	– gates	– main/nodal distribution buildings	– IT
– **pathways**		– main transformer 6/120 kV AC enclosure	– cables

Many solar power plants are surrounded by footpaths and hiking trails. Therefore, solar power plants must not only be protected from intentional intrusion, but also prevented from accidental access or entry. It should be noted that such power plants not only pose a hazard due to their operating principle (~1000 V DC or high voltage >1000 V AC), but also pose an increased risk of lightning strikes in stormy weather. It is important to note that lightning strikes are not only a direct hazard, but can also cause severe shocks to pedestrians and tourists walking along the road, due to the step voltage, which can spread through the ground, even much further away from the power plant. It is therefore of the utmost importance that the area around the power plant is also monitored, within the limits of the law (Abubakar et al., 2021; Ali et al., 2024). Artificial intelligence-based monitoring systems can play a key role in this process. AI-based cameras and sensors can analyse movements in the environment in real time, identify people and animals, and distinguish suspicious activities from everyday movements (Singh et al., 2024). The system can thus detect not only intrusion attempts, but also if a tourist or passerby accidentally wanders into the danger zone. The AI-powered systems are able to send automatic alerts to operators or to the live alarm service, which can warn nearby people of the danger if necessary. The most basic protection is still provided by mechanical units: gates, fences, walls and other barriers that mark the boundaries of the object and prevent or slow down intrusion (Koller, 2016). However, their efficiency can be significantly increased by a monitoring system with artificial intelligence, which provides continuous and intelligent monitoring. Solar power plants are both "brick buildings" and container units. The reason for using a container is that the equipment consists of pre-typed components and is preassembled. The masonry of the buildings and containers is strong and resistant to extreme weather conditions, so that the windows

are the weak link. Artificial intelligence can also be used here, for example in the form of access control systems with smart sensors and biometric identification to prevent unauthorised access. Artificial intelligence can therefore play a significant role not only in intrusion protection but also in keeping the plant environment safe, helping operators to make more efficient and faster decisions to deal with emergencies.

3 Electronic intrusion detection systems

The structure of electronic intrusion detection systems is usually compared to the structure of an onionskin, with layers of perimeter, surface, area and object protection (Figure 1). Personal protection is also included, but this is not relevant for a solar power plant. Intrusion detection systems also include alarm signalling and remote monitoring communication (Utassy, 2009).

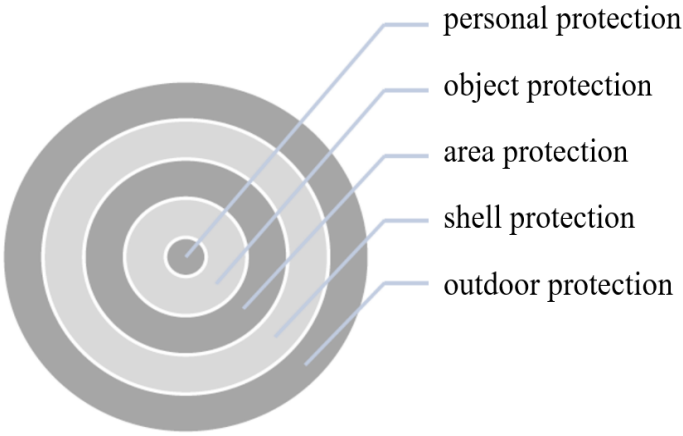

Figure 1: Onionskin protection structure

3.1 Elements of outdoor protection

An important aspect of outdoor protection devices is that they should be resistant to environmental impacts. These include UV radiation, wind, precipitation, dust and temperature fluctuations. Solar power plants are mostly installed in the countryside or on the edge of settlements, so false alarms, mainly caused by vegetation and animals, must be taken into account, but also pedestrians and tourists. Outdoor

electronic protection is based on changes in movement, vibration, pressure or some other physical parameter. The use of artificial intelligence in this area is a major advantage, as AI-based systems can identify real threats and filter out false alarms, increasing the effectiveness of the system (Tóth & Tóth, 2014).

3.1.1 Motion detection (outdoor)

The operation of the motion sensor is based on the temperature radiation of the human body. It detects the wavelength in the infrared spectrum and its variation in intensity, and signals above a certain deviation value. The disadvantages of outdoor applications are short range and false alarms due to sudden temperature changes. Artificial intelligence can play a key role here too, as AI-based camera systems can continuously analyse sensor data, identify the source of movement and distinguish humans from animals or environmental influences. Such systems are becoming increasingly accurate through machine learning, and can therefore minimise false alarms. In addition, AI-based systems can automatically detect and signal when camera lenses become obscured or clogged, ensuring continuous and reliable operation (Oktel Kft., n.d.).

3.1.2 Security fencing

One of the basic elements of fence protection is the use of vibration sensors, which are fixed to the boundary element (fence, wall, railing, etc.) and detect its deformation and vibration. Weather conditions, especially strong winds and the presence of animals, can cause false alarms. AI-based systems can also help in noise filtering here, as they can analyse vibration patterns and distinguish genuine intrusion attempts from harmless environmental effects. For sensor-based sensors, artificial intelligence can be used to analyse detected vibrations and movements in real time. AI is able to integrate data from multiple sensors (such as piezoelectric, coaxial, linear magnetic or optical technologies) and generate more accurate alerts. Step sensors and infrared barriers also benefit from the use of AI, as it can detect the movement of people and animals and anticipate potential threats (Tóth & Tóth, 2014). For infrared barriers, AI not only detects signal loss, but also analyses the movement pattern between the transmitter and receiver, providing more accurate protection (Szandtber & Márkus, n.d.). AI plays a particularly important role in license plate recognition systems. AI-based number plate recognition systems are

able to quickly and accurately identify vehicles and decide on access rights based on the information stored in the database. In addition, AI can help the system to learn and evolve, for example, by treating unknown number plates as warnings or managing periodic access authorisations (Bunyitai, 2011; Fogarasi, 2020).

3.2 Surface protection

Surface protection is designed to prevent intrusion through the structural elements of buildings. To this end, windows should be equipped with opening detectors, glass surfaces with glass break detectors and insufficiently solid wall structures with wall break detectors. The use of artificial intelligence in this area can take security to a new level, as AI-based systems can continuously monitor and analyse sensor signals and identify correlations, reducing false alarms and increasing the ability to react quickly (Tóth & Tóth, 2014).

3.2.1 Open sensors

Open sensors operate on a mechanical or magnetic principle. One of the best-known types of magnetic sensors is the reed-opening sensor, which consists of a pair of contacts and a permanent magnet in a glass tube filled with an air-cushioned or neutral protective gas. When the magnet comes close to the sensor, the contacts close and signal the system.

Artificial intelligence in this system increases efficiency by analysing sensor signals to detect suspicious patterns, such as the movement of a slowly, carefully opened door or window, which might not be an obvious alarm situation for a conventional system. AI-based algorithms are able to combine data from other sensors, such as motion sensors and cameras, to create a more accurate picture of what is actually happening. Micro-switches are mainly used in places where the sensor has to operate with little force, such as switch cabinets and fitting boxes. AI can also be useful here, as the system can monitor the status of cabinets and other equipment and automatically send an alarm if, for example, a switch cabinet is left open. In high-security areas, several signal catches and counter-bars rotated relative to each other are used to prevent tampering. Artificial intelligence can also optimise the operation of these systems by learning and recognising signals generated during normal

operation, so that unusual or tampered events can be detected immediately (Szandtber & Márkus, n.d.; Tóth & Tóth, 2014).

3.2.2 Glass break detector

Glass break detectors are not normally used in solar power plants, but in facilities with education and visitor centres, their use is essential. There are two main types of glass break detectors: vibration-based and contact-based. Piezoelectric vibration detectors detect high-frequency vibrations generated by breaking or cutting glass by fixing them to the glass surface to be protected. By incorporating artificial intelligence (AI), these sensors can analyse vibration patterns and minimise false alarms, for example by distinguishing vibrations caused by objects falling on glass from real breaking events. Contact glass break detectors use a conductive metal layer on the glass surface, which breaks in the event of break, thus signalling to the security system. With the help of AI, such a system can be combined with other sensors, such as cameras or acoustic analysis algorithms, which can refine alarms based on sound patterns. Acoustic glass break detectors use a condenser microphone to detect the sound vibrations generated during break. With the help of AI, these devices can learn to distinguish between real glass break and other sounds of similar frequency (such as the rattling of a pot or loud banging), thus significantly reducing false alarms (Szandtber & Márkus, n.d).

3.3 Space protection

The purpose of space protection is to monitor movements within the area to be protected. The sensors are either focused on the specific area to be protected or installed at entrances and corridors. Since the interior of solar power plants usually consists of narrow service corridors, space protection is not typically used here, except in demonstration and training rooms. The most common space protection device is the passive infrared (PIR) motion detector, which detects infrared radiation emitted by living bodies. With the help of AI, these sensors can more effectively analyse detected movements and can distinguish human movement from signals generated by animals or environmental factors (e.g. air currents). Ultrasonic and microwave motion sensors are based on the Doppler effect: they emit a wave of a given frequency and then monitor the frequency variation of the reflected signal. The use of AI in these sensors can also help to detect false alarms by analysing

movement patterns and taking into account environmental effects such as wind or shadow movement (Tóth & Tóth, 2014).

3.4 Object protection

A significant proportion of the inverters used in solar panels are mounted in mounting brackets. To facilitate maintenance, they can be lifted off by their handles like a briefcase and transported to the service centre. These inverters can sometimes be worth millions of forints, so they should be specially protected. One such protection device is a weight sensor.

4 Other intrusion detection support systems

4.1 Cameras

Cameras are not intrusion detection devices per se, but the signal they transmit can be used for alarms by image processing software. Such software processes the image information using a large database and "artificial intelligence". Their great advantage is that they can use filters and lenses to monitor the area and the surroundings of the object to be protected from a great distance, even at night - while complying with the law. By using smart cameras, you can reduce the workload on your staff and reduce the number of people needed to monitor the area (Berek, 2014).

4.2 Drones

Drones (actually UAVs) are now very common tools in the operation of solar power plants. Their main role is to support maintenance and increase operational safety. One important task in the maintenance of solar fields is to check the cleanliness of the solar panels. The easiest way to assess this is by aerial drone survey. And in maintenance, it is used to detect hotspots - abnormal solar panel, cell heating. Such flights provide an opportunity to assess damage to protection devices (e.g. fences). They can show traces of unusual movements or preparations for intrusion (e.g.: strike making) (Szalkai, 2021).

5 Summary

Various intrusion detection and protection systems are used to ensure the security of solar power plants. Surface protection uses opening and glass breakage detectors to monitor intrusion attempts, while area protection uses motion detectors to monitor protected areas. Valuable assets such as inverters are protected by weight sensors and other object protection technologies. Security systems are becoming more advanced and the integration of artificial intelligence (AI) is opening up new possibilities. AI-based cameras can automatically detect suspicious movements, filter false alarms and provide night-time surveillance. Smart drones can patrol autonomously, identify intrusion routes and transmit real-time images to the security centre. The use of AI increases the efficiency of intrusion detection systems, reduces false alarms and optimises the work of security personnel. In the future, intelligent security systems will increasingly be able to operate autonomously, predictively identifying potential threats and taking preventive action.

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Digital Transformation in the Hotel Industry: A Study of Four-Star Hotels in Szeged

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With the evolution of technology, the landscape of hotel management is set to undergo a remarkable transformation, reshaping operations and enhancing guest experiences like never before. This study investigates the pervasive impact of technology on hotel management and customer experience. The main goal is to explore the various ways digital innovations are revolutionizing guest services and enhancing operational efficiencies in the hotel industry responding to the highly volatile external environment. The secondary research part relied on literature review, predominantly sourced from electronic publications, press releases, and systematic website content evaluation. The market phenomena were examined through interviews with hotel managers of four-star hotels in Szeged. The findings indicate that enterprises in the centre of Southern Great Plain region (Hungary) have adopted IT-based solutions to enhance market efficiency to differing extents. The study identifies improvements in operational efficiency driven by IT-based solutions; however, guest-facing digital innovations remain limited. The study examined 11 units with official rating, enabling the results to be contextualised inside a specific market, while underscoring those trends identified internationally in small open economies are swiftly manifesting locally. The innovation of the research is in its market adaption and serves as a benchmark resource for hotel decision makers.

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1 Introduction

Hotel technology is categorized into five categories: front desk and back-office technology, meeting and events, restaurant and banquet management and customer service technology (Bulchand-Gidumal & Melián-González, 2015). This article explores only front desk technology, with a focus on presenting customer service technology in the guest areas.

Front desk technologies facilitate personnel to gain access into extensive customer information and seamlessly integrate it, ensuring efficient service delivery while minimizing both operational time and costs. Advanced front desk technologies elevate the service experiences of hotel guests by delivering timely and personalized assistance (Singh et al, 2023).

The front desk technologies mostly employed by front desk staff, cashiers, cleaning, and reservation departments. These technologies can include booking systems, reservation software, guest communication tools, and check-in kiosks, all of which help to create a seamless and efficient interaction between staff and guests.

Customer service technology focuses on enhancing guest satisfaction through personalized services and feedback mechanisms. Using customer service technology to collect feedback through surveys and reviews can help the hotel identify areas for improvement and address any issues promptly, ultimately enhancing overall guest satisfaction. The utilization of intelligent mobile technologies and connectivity enables real-time acquisition and updates of consumer data, resulting in ongoing enhancement of guest customization.

Together, these technologies work cohesively to create an enjoyable experience for hotel guests.

2 Theoretical Background / Literature review

2.1 Front desk operations

2.1.1 Reservation

Smart computerized solutions can well improve hotel capacity distribution by analysing market demand, competitor pricing, and booking patterns in real-time. This allows hotels to adjust prices dynamically, attracting more guests and increasing revenue (Bisoi et al., 2020). Advanced data analytics provides insights into customer behaviour, booking trends, and seasonal fluctuations, enabling hotels to make informed decisions about staff allocation or marketing strategies. Revenue Management Systems use algorithms and data analysis to provide pricing support and capacity management strategies, while channel management systems help hotels manage multiple distribution channels simultaneously (Guillet, 2020).

Dadić et al. (2022) detailed those smart computerized solutions can streamline the booking process, providing real-time availability updates and bookings across multiple channels. Guest profile management allows hotels to create personalized experiences and targeted marketing campaigns, increasing the likelihood of repeat bookings and improving occupancy rates. Capacity forecasting with predictive modelling helps hotels anticipate future occupancy and make informed decisions about pricing and inventory management (Bouchareb, 2023).

Antonio et al. (2019) states that flexible cancellation policies and dynamic pricing models powered by AI enable hotels to adjust prices in real-time, maximizing revenue and ensuring competitive pricing. By leveraging these solutions, hotels can achieve more efficient capacity distribution, enhance guest satisfaction, and ultimately increase profitability.

2.1.2 Check-in procedures

The check-in process is crucial for a guest's stay, and a smooth and efficient process can leave a positive first impression. Training front staff to handle check-ins professionally and having systems in place to address issues like room availability or special requests can help streamline the process and enhance guest satisfaction.

Mobile and web check-in or use of chatbots can improve guest options and overall experience by minimizing queuing times and allowing guests to interact at their convenience (Singh et al, 2023). As the economy increasingly relies on advanced technology, hotel guests are becoming producers and consumers, with an entirely automated online check-in and check-out system allowing them to independently handle routine procedures. However, relying solely on technology may result in a lack of personal interaction and personalized service for guests (Zeithaml et al., 2017).

2.1.3 Stayover procedures

Concierge services enhance client experience, retention, and satisfaction rates, however, executing these services can be challenging due to evolving visitor demands. Digital technologies have been used to improve concierge services, such as online reviews, wireless technology, and artificial intelligence (Das, 2023). These technologies can streamline stayover procedures, provide personalized recommendations, and improve customer service, leading to higher levels of guest satisfaction and loyalty.

2.1.4 Check-out procedures

Smartphones allow guests to check their bills, update payment information, and request housekeeping services before entering the lobby. Check-out is also facilitated through kiosks, mobile apps, or the hotel front desk. The Property Management System (PMS) connects with credit authorization systems for efficient payment processing. This integration ensures a smooth check-out process, reducing last-minute surprises and ensuring quick room turnover. Contactless payments, such as digital wallets and contactless cards reducing the need for traditional equipment for card transactions (Bouchareb, 2023).

2.2 Guestroom digitalisation

Hotels now offer rooms with advanced technology and a wider range of entertainment options similar to private homes. Digitalization aims to provide users with personalized experiences, reducing staff strain and improving customer experience.

2.2.1 Electronic locking systems

Intelligent room technology, including keyless entry systems, biometric identification, and smart doorbell cameras, enhances security and guest experience. These technologies reduce the risk of misplaced or stolen keys, while biometric verification adds an extra layer of protection (Das, 2023). In-room safes offer a secure, convenient solution for guests to store belongings.

2.2 In-room control solutions

In-room control consoles regulate room amenities, lighting, and temperature to customize the room for business, pleasure, or sleep environment. Autonomous lighting and climate control systems improve energy efficiency by adjusting settings based on guest preferences and occupancy levels (Das, 2023).

2.3 Entertainment and wellness solutions

High-definition smart TVs with streaming capabilities allow guests to access the preferred contents, stream their personal Netflix through in-room pay-per-view digital content platforms. In-room game systems, fitness systems, and artificial intelligence (AI) can also enhance the guest experience. AI and guest history can optimize bookings for recreational facilities, improving guest access and increasing hotel revenue (Bisoi, 2020).

2.4 Guestroom services supported by digital solutions

Intelligent room technology, such as high-speed Wi-Fi, USB charging ports, and smart workstations, promotes productivity and supports leisure activities. Voice-activated assistants like Google Assistant provide guests with quick access to information and personalized recommendations. Additionally, the use of devices for meal ordering and the use of historical data and trends allowing hotels to anticipate guest preferences, personalize services, and create memorable experiences (Bharwani & Mathews, 2021).

3 Methodology

The study seeks to find out whether four-star hotels in Szeged are taking advantage of digital technologies to enhance the hotel guest experience, or whether they are limiting the digital services they provide to the level of compliance with the legal environment. As digitisation is a complex subject that requires extensive study, exploratory research methodologies help understand operators' perspectives, experiences, and attitudes towards ICT technology. In domains where theories may not fully explain organisations' practices, exploratory qualitative research is suitable. A paradigm that allows incremental data collection and processing based on emergent patterns and categories is a strength.

The sources of data used in this study consist of semi-structured interviews and analysis of hotel websites besides the literature review. These methods are chosen as they enable the generation of detailed knowledge concerning the studied research questions. In Szeged, 12 facilities operate as four-star hotels; however, only 11 are recorded in the official registry of szallashelyminosites.hu, excluding the Science Hotel. The survey was administered to the managers of these units from 1 to 15 March 2025. The enquiries pertained to aspects of digitalisation that cannot be obtained via hotel websites. None of the unit managers contributed to the identification of the hotel in the text of the study.

4 Results

4.1 The hotel industry of Szeged

Szeged, a significant cultural and commercial centre in Southern Hungary, boasts a rapidly evolving hotel sector. The lodging options are varied, encompassing both luxury hotels and intimate, family-operated guesthouses independently managed or operated under a brand. The majority of hotels are situated in the downtown, capitalising on their closeness to tourist attractions. The vicinity of Széchenyi and Dóm Square is especially favoured by tourists. On the outside of the city and in adjacent locales, guesthouses and B&Bs provide alternate options. The hotel industry is intricately connected to conference, cultural and spa tourism.

The quality of hotel services has also evolved in the past years. The recent development of new hotels has heightened rivalry among accommodation establishments, particularly in the city centre and near important transport connections. Newly opened hotels have augmented their room capacity and enhanced service quality by introducing new leisure and recreational amenities. The diversification of the city's tourism sector, encompassing cultural events, festivals, and sporting activities, has led to increased hotel occupancy rates. The increasing number of services and the distinction among hotels is fundamentally driven by demand trends. However, hotel occupancy rates notably rise throughout the tourist season, particularly in the summer months and during festivals.

4.2 Requirements for four-star hotels

In Hungary, the classification of accommodations (by kind and quality) is mandatory; the hotel rating system is similar to the Hotelstars criteria. The certification remains valid for three years, during which hotels must consistently comply with the criteria of their category. The standards encompass hotel operations, services, common and guest areas, establishing a minimum service standard for properties ranging from 1 to 5 stars. Extra points may be obtained by fulfilling the optional services, which can be utilised to attain a superior level if the minimal points for this category are satisfied, although only the inferior category is achieved in mandatory services. The requirements have been revised effective 16 March 2025. The criteria for each quality class vary, but the requisites for digital technology in 4-star hotels only include: cashless payment systems, televisions with international channels, electrical outlets (with adaptors), telephones, Wi-Fi, printing facilities, a website, and the management and analysis of guest complaints.

Moreover, hotels must implement a compliant PMSs that deliver data in real time to National Tourist Information Centre, to National Tax and Customs Administration and to Guest Information Closed Database, which handles visitors' anonym personal information. The compilation of compatible software comprises 45 applications from 40 distinct businesses (Hungarian Tourism Quality Certification Board).

5 Discussion

Among the surveyed hotels, one is affiliated with the Novotel brand (Accor group), one belongs to the Hungarian Hunguest Hotels chain, and one is operated under a management contract by Accent Hotels. Three hotels are managed by a single operator. In accordance with the particular rules of Hungary, all units utilise PMS either developed in Hungary or modified for the Hungarian market: six units employ Hostware, four use Previo, and one utilises Sabeeapp. Despite Hostware providing a booking engine, its users utilise RoomSome or RESnWEB for website booking management. Users are often satisfied with the functionalities of their selected software; nonetheless, two hotels utilising Hostware are contemplating shifting to a more contemporary cloud-based solution. None of the units have an application specifically tailored for guests to improve their experience. Novotel provides the All.com application for managing reservations, whilst Hunguest offers a digital restaurant menu on the hotel website.

The ratio of direct to indirect online reservations for units generally fluctuates with the seasons; nonetheless, the predominant distribution is evenly split at 50% from own websites and 50% from intermediary sources. Two units are absent on booking.com, and one is missing from the popular Hungarian online travel agent site, szallas.hu. Five units lack dynamic pricing and instead implement varying room rates based on seasonal changes on their booking platforms. All except one of them provide package deals; however, these are not based on a dynamic ensemble. Certain units - RESnWEB users - provide additional services that can be incorporated into the reserved rooms during the booking process. Only two units have adopted a special AI-assisted solution to enhance bookings (e.g., Peaq Plus, STR, OTA Insight).

Check-in occurs traditionally on-site at the surveyed units, with just two properties allowing for a reduction in administrative effort by submitting data in advance. The mandatory scanning of the travel document is unavoidable in this instance as well. In the absence of digital check-in, guests may generally submit requests for a room or its amenities during the booking process or via email to reception. 73% of properties fail to utilise the data provided by national-level mandated systems, which are deemed inadequate in quality or scope.

Hotel stayovers are the least supported electronic solutions. Despite the literature emphasising the beneficial effects of these applications on guest experience, their use by hotels in Szeged remains minimal. One hotel still employs a mechanical door opening system, whereas five do not utilise guestroom electricity management system. Among the 11 units, all provide essential in-room services including Wi-Fi, television, telephone, radio, printing upon request, and cashless payment; however, limited additional services are offered. While the optional services "individually controlled air conditioning" and "in-room kettle" are available in all rooms, only two hotels include a Nespresso coffee machine, and one unit offers an electronic blackout function. No applications or voice-activated lighting or heating systems are accessible anywhere. Netflix is offered in only two hotels, neither of which has a gaming console or an integrated sound system. Direct USB charging is offered in only five units. Only 2 hotels use an AI-supported solution to understand the consumption habits of their guests.

Contactless check-out is limited, with merely two units providing this service; in case of pre-payment, only the room card must be left at the reception. It is regrettable that guests are unable to review their bill in advance at any of the hotels, highlighting a deficiency in transparency. Furthermore, cashless card-free payment methods (such as Revolut or Google Pay) are not prevalent, there are no available options for such transactions anywhere.

The utilisation of data produced at the front desk for Housekeeping is limited in the examined units, relying solely on the reporting and roster supplied by the PMS. Two units exclusively utilise the asset register provided as a module within the Hostware PMS.

6 Conclusions

The newly established units failed to leverage the technical benefits available, opting instead to commence operations with conventional equipment and services to fulfil the criteria of the four-star classification. The existing units continue to utilise their current digital solutions, exhibiting little desire for change despite the presence of more advanced digital alternatives on the market.

This resistance might originate from the following areas.

- Cost and investment: the introduction of modern technologies requires a significant initial investment, which can be a major barrier for many hotels, especially smaller ones.
- Staff training: learning to use new systems is time-consuming and staff training is an additional cost. Employees can also learn from each other, which saves costs.
- Security concerns: digital systems can be vulnerable to cyber-attacks, which can mean sensitive guest data is compromised. Data protection should be a priority.
- Respect for tradition: personal contact and traditional hospitality are important in hospitality, and many fear that technology could impersonalise the service.
- Resistance to change: many in the hotel industry are attached to tried and tested methods and are averse to innovation. This is especially true for older managers.
- Customer base: the customer base is very mixed, with many older people not liking or able to use modern technology. Therefore, online and offline solutions are often used in parallel. For family-friendly and youth hotels, the level of digitalisation is expected to be higher.
- Systems integration: lack of compatibility with existing systems can also be a barrier to digitalisation. In such cases, systems developed for the hotel's needs can provide a solution.

The above issues generally arise in the realm of full system integration, indicating significant potential for development in hotel guest room entertainment. Digital enhancements to guest rooms are predicated on visitor experience, incurring no training expenses. Adaption of Service Blueprinting framework may enhance the study by mapping touchpoints where digital interventions could improve guest experience.

Further area of interest of the research is to examine the supply side of the four-star hotel industry in Szeged, assessing if the general degree of digitisation aligns with demand requirements or is predominantly tailored to the operator's competencies

and/or making a comparative industry analysis to benchmark local results against international experiences.

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Sustainable Corporate Governance and Stakeholder Engagement: Analyzing the Role of Stakeholder Integration in ESG Reporting

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Aim: This research paper focuses on the identification and comparison of stakeholder reporting in practice. It covers the recognition of key stakeholders, identification of channels of dialogue, and the integration of stakeholder interests into corporate governance. **Methodology:** A content analysis methodology has been used to conduct research on stakeholder reporting by selected companies. Based on the research results, a comparative analysis has been carried out to examine which ESG reporting areas contain the most detailed stakeholder-related disclosures and to what extent companies include the interests of their key stakeholders in their corporate governance. **Findings:** Based on the research results, it can be concluded that companies include the interests of key stakeholders in the process of sustainable management and corporate governance. The inclusion of key stakeholders is particularly evident in terms of their identification, the gathering of information, and the formation of groups of key activities relevant to the company. **Value:** The main value of this research paper lies in gaining additional insights into the inclusion of key stakeholders in corporate governance and sustainability reporting in practice. It provides further understanding of the areas related to key stakeholder engagement and offers potential recommendations for the continued inclusion of stakeholders.

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1 Introduction

Stakeholder engagement has become a key component of corporate governance, particularly in the context of sustainability reporting and compliance with regulatory changes, such as the Non-Financial Reporting Directive (hereinafter NFRD), Corporate Sustainability Reporting Directive (hereinafter CSRD), and Taxonomy or Corporate Sustainability Due Diligence Directive (CSDDD). Managing stakeholders represents one of the essential aspects that help companies identify and manage key risks and opportunities in the field of sustainability. Companies must integrate the interests of key stakeholders into their governance to align corporate management with stakeholder expectations and ensure sustainable and long-term business success (Primec & Belak, 2022). Care for the environment, society, governance, biodiversity, climate change, etc. has become an increasingly significant factor in the management of business entities. The concern for sustainable areas is increasingly being integrated into corporate governance, and companies are striving to change the management and leadership process in a way that influences long-term sustainable operations (Staudt et al., 2023).

With global initiatives, the need to align the needs of key stakeholders with the interests of the company has grown even more, leading to the need for the development of strategies and increasing efforts toward coordinated and integrated sustainable operations, both at the individual level and at the organizational level. At the EU level, in recent years, numerous measures have been observed through which the EU has sought to promote sustainability, sustainable development, sustainable governance, and transparent information reporting. These measures have encouraged business entities to gain a better understanding of their key stakeholders and to report broader information related to the environment, society, and governance transparently. One of the key aspects of governance from a sustainability perspective is also the inclusion of external and internal stakeholders in the management and leadership process of the company. In doing so, companies build trust and reduce risks, which strengthens trust between the company, key stakeholders, and the surrounding environment in the long run (Čufar & Primec, 2022; Čufar et al. 2024, Nygren & Hallan, 2024).

The purpose of this paper is to examine the identification of key stakeholders by companies in practice. Based on the research findings, we expect to gain additional insights into the procedures and the integration of key stakeholders' interests into the management and corporate governance of the companies in the field of sustainability.

2 Theoretical Background/Literature Review

The stakeholder theory in connection with corporate governance can be found in various publications and literature. According to the original concept developed by Freeman, the theory is used to understand the relationships and frameworks between a company and its stakeholders (Freeman, 1984). In the context of corporate governance, such relationships contribute to a better understanding of the needs and interests of key stakeholders and their consideration in the company's management process. In the governance process, companies do not focus solely on the interests of narrow stakeholder groups but strive to align their actions as closely as possible with stakeholder expectations. The stakeholder theory facilitates the development and foundation for distinguishing broader social issues from the concerns and needs of individual stakeholders (Harrison et al., 2015). Compared to shareholder theory, stakeholder theory advocates for and expands corporate responsibility to a broader range of key stakeholders, such as employees, customers, the community, suppliers, and the environment. The theory serves as a crucial tool for corporate management in the business environment. In connection with socially responsible management and sustainability reporting, stakeholder theory provides a foundation that enables companies to disclose a broader range of information and risks, addressing and informing a wider group of stakeholders. By disclosing more sustainability-related information, companies can gain stakeholder support more easily, thereby improving their business performance (Clarkson, 1995; Reverte 2009).

The term corporate social responsibility has evolved over the years, gaining an increasingly broader meaning. In the EU, the concept of CSR was initially implemented voluntarily where companies incorporated social, environmental, and governance indicators into their operations on their initiative. However, with ongoing crises and the collapse of organizations, it became evident that voluntary reporting was insufficient for integrating CSR into corporate governance systems.

Consequently, the EU introduced legislation, such as the NFRD, CSRD, CSDDD, and the EU Taxonomy to ensure that companies incorporate sustainability indicators into their management processes and inform key stakeholders about the risks and opportunities extending beyond financial performance. Thus, stakeholder management represents a key measure through which companies ensure the sustainable integration of CSR into their governance while considering the interests of their stakeholders. Additionally, it provides stakeholders with opportunities and communication channels for exchanging information (Primec & Belak, 2018; Staudt et al., 2023).

One of the first legislations in the field of sustainability reporting and the reporting of key stakeholder information in sustainability reporting is the NFRD. The directive required companies to report information related to environmental impacts, social aspects, and corporate governance. The reporting obligation applied to all public interest entities that had more than 500 employees on the balance sheet date. Although such reporting applies only to a certain scope of companies, the legislation and regulatory measures represent one of the key measures that encourage the integration and inclusion of key stakeholders in the corporate governance process. Based on the review of the NFRD, numerous shortcomings were identified, which represented deficiencies in reporting and the comparability of reported data. To address these shortcomings, the EU adopted the CSRD, which more precisely defines sustainability data reporting. It is expected that, as a result, the reporting of information in line with the integration of key stakeholder interests will improve in the future and become more detailed and transparent at the corporate level.

3 Methodology

As part of the research, a multiple case study was used to analyze the sustainability reports of selected companies. This method enables a detailed definition of the studied phenomenon within real-life circumstances and the context of the chosen company. It allows for the examination of the phenomenon in a specific environment using multiple data sources and analyses. The analysis facilitates the acquisition of information and its interpretation in a way that thoroughly explains the reasons and circumstances behind specific activities related to the studied phenomenon (Paolone et al. 2023; Lina et al., 2023; Voss et al., 2008).

The method of content analysis was used for data collection and analysis. The content analysis method was chosen because it has already been used for analyzing similar research and qualitative studies. The selected method is suitable for the present analysis because it allows for the examination of qualitative reporting by companies and its interpretation. The sample on which the research was conducted includes six companies from Slovenia, operating in the sectors of manufacturing, insurance, and banking. For each of these companies, the study examined whether the company (Paolone et al. 2023; Lina et al., 2023; Voss et al., 2008):

- identifies their key stakeholders in their sustainability reports,
- specifies communication channels,
- identifies the information received from key stakeholders, and
- indicates how this information is implemented in their management and leadership process.

The analysis was conducted based on the annual report or a separate sustainability report published by the selected business entities for the chosen reporting year. The reports were analyzed for the period of 2023.

4 Results

The research results indicate that all selected companies report data on their key stakeholders in their annual or sustainability reports for the year 2023. More specifically, all analyzed companies implement their key stakeholder groups. However, differences arise in the identification and formation of individual groups. It can be observed that companies that identify their key stakeholders in more detail—for example, by specifying exact stakeholders rather than grouping them into broader categories—tend to provide more detailed information on how key stakeholders influence the company and how the company impacts its key stakeholders.

Based on the information obtained from annual or sustainability reports, the extent to which companies report on communication channels with their key stakeholders was examined. Evidently, that reporting varies among companies. Some companies, particularly those in the insurance and banking sectors, provide more detailed

reports on the communication channels they have established with key stakeholders and how they obtain and utilize the information received from them. Such reporting offers a more detailed insight into how companies establish contact with their key stakeholders and how different stakeholder groups can engage with the company. It is also noticeable that some companies report detailed information on when they had contact with specific stakeholder groups during the reporting year.

From the analysis of the reporting of data obtained from key stakeholders, it can be observed that some companies provide information in a generalized manner, consolidating multiple stakeholder information into a single group. In such cases, a detailed explanation is missing regarding which specific stakeholder group provided the information what information was received, and what criteria were used for its assessment. The information is presented in a cumulated form, and the company does not establish a clear link between the implemented measures within the company and the information received from key stakeholders (Čufar & Primec, 2022; Čufar et al. 2024; Primer & Belak, 2018).

In contrast, some companies provide more detailed disclosures on the specific information obtained from key stakeholders and how this information was used for future assessments of material topics and the development of sustainability management strategies. This type of reporting provides companies and their key stakeholders with more detailed insights into which stakeholder groups are relevant to the company and how the information from individual stakeholder groups has been utilized to adjust strategies and planning in the field of sustainability.

5 Discussion

Based on the research findings, regarding the identification of key stakeholders, it can be summarized that the analyzed companies strive to report data on key stakeholders, engage in their identification, and define them within their annual reports. Evidently, all companies have at least some information about the key stakeholders they identify within their company. However, fewer companies provide detailed reports on specific types of key stakeholders and the impact they have on the company or vice versa (Čufar & Primec, 2022; Nygren & Hallan, 2024).

In the analyzed reports, some companies provided a detailed description of their key stakeholders, precisely identifying their level of importance for the company. From the perspective of reported data in annual reporting, the results indicate that companies are increasingly committed to integrating the interests of key stakeholders with those of the company, thereby co-shaping strategies and the management and leadership process in the field of sustainability (Freeman, 2010).

When examining questions related to communication channels, it can be observed that while some companies report information in detail, others provide more general information at the level of individual stakeholder groups. Information on how key stakeholders communicate with the company and the specific communication channels used enhances transparency and the content of reported information, providing greater insight into the exchange of information between the company and its key stakeholders. To ensure the transparency of reported information, some companies explicitly specify the time period in which they were in contact with key stakeholders and the outcomes of the information exchange (Freeman, 2010; Čufar & Primec, 2022).

Within the reported data, the information that companies disclose in their annual reports depends on whether they report on their key stakeholders in a general manner or define them in detail at an individual level. Companies that provide more detailed reporting on their key stakeholders also tend to report more specifically on which information they received from which key stakeholders and how the data exchange took place. Companies that identified key stakeholders at a surface or group level typically only reported the information obtained through communication but did not specify in detail which key stakeholders provided the information or for which key stakeholders the information was relevant. This type of reporting reduces transparency regarding communication and the information that the company reports concerning its key stakeholders. In the context of implementing information into sustainability strategies and plans, it can be observed that companies that reported key stakeholders in detail also provided more specific information on how the interests of key stakeholders were integrated into their strategies and management processes. This type of reporting enhances transparency and provides an overview of the measures taken by the company based on the information received from key stakeholders (Čufar et al., 2024).

6 Conclusions

Key stakeholders play a crucial role in the integrated and comprehensive approach to the implementation of sustainable strategies within the management and leadership processes of a company. Stakeholder management is essential for effective corporate sustainability reporting and sustainable corporate governance. For comprehensive and detailed information disclosure, legislation on key stakeholders provides a framework that companies follow to ensure the reporting of complete and transparent information. By integrating innovative practices and regulatory requirements, companies are encouraged to achieve long-term sustainability and competitiveness. In the future, research could focus on analyzing key stakeholders based on data reporting over a longer period (several years) and the CSRD requirements, which will come into effect in the near future, and has already been implemented into Slovenian legislation. Based on the results, it will be possible to determine in more detail the impact of the legislation on the reporting of information about key stakeholders, how companies have reported information about their key stakeholders over time, and whether their interests have been integrated into the company, its strategies, and plans, contributing to a sustainable management and leadership process.

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Digital and Hybridization Business Models: Contribution to Sustainable Transition

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The transformation of business activity has led to the evolution of business models in the creative industries. This paper explores the evolution of business models in the creative industries in the context of digital transformation and hybridization. By applying theoretical models such as concentric circles, value chains, and the cultural cycle, it examines how creative and cultural enterprises adapt to the digital economy. The research highlights the growing interdependence between digitalization and hybridization, emphasizing the emergence of diversified revenue streams and collaborative business strategies. The findings show that digital transformation not only redefines value creation and consumption in the creative industries but also contributes to the Sustainable Development Goals (SDGs), particularly Agenda 2030. The study emphasizes the importance of fair compensation models, inclusive platform access, and local monetization strategies to ensure equitable growth. It, also, underscores the creative industry's role as a transversal driver of sustainable development. This paper provides a conceptual framework to understand the shifting dynamics of the sector, offering practical implications for stakeholders and policymakers aiming to foster innovation and sustainability in the creative economy.

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1 Introduction

Digital transformation has triggered fundamental changes in the business models of the creative industries, leading to the emergence of hybrid models that combine creative production, digital distribution, and collaborative economic approaches (Li, 2020). An analysis of the concentric circles model, value chains, and the cultural cycle shows that these models enable greater flexibility, accessibility, and sustainability of cultural products and services (A Research Agenda for Creative Industries, 2019).

Collaboration brings numerous advantages for creative industries, such as shared platforms, reduced distribution costs through digital platforms, and access to a larger number of users. The cyclical life cycle of creative industries emphasizes the need for diversification, which points to the creation of gaps related to the relationship between the Digitalization and Hybridization index, as well as, value gaps between digital platforms and small businesses within the creative industries.

Changes in business models within creative industries, driven by digital transformation, impact the 2030 Agenda and the overall creative sector (UNESCO, 2019; Larasati & Satari, 2021). The relationship between creative industries and the 2030 Agenda is transversal, and hybrid business models will contribute significantly to this relationship.

The analysis of the new business models provides a current insight into the changes occurring in the creative industry and impact on other sectors, as well as, an understanding of the possibilities for collaborative action in the future business context, particularly from the perspective of their influence on sustainable development.

2 New business models in the creative industry

This study applies a qualitative research methodology aimed at analyzing the development of business models in the creative industries under the influence of digital transformation and connection with the 2030 Agenda. The research is based on secondary sources and theoretical approaches, with a focus on interpretative analysis of existing models and practices. The approach is both descriptive and

interpretative, allowing for a multidimensional examination of contemporary business models and their positioning within a broader social and economic context. The main research methods used include:

1) **Content analysis** of relevant academic and professional literature, including Reports from international organizations (UNESCO, European Commission) and academic works in the fields of cultural policy, digital economy, and creative industries.

2) **Case study analysis** of hybrid business models, which enables the identification of concrete examples of best practices in the context of digital distribution, collaborative economy, and platformization (Li, 2014; Feng, 2020; Betzler & Leuschen, 2020; Massi et al., 2021; Priyono et al., 2021) and

3) **Theoretical mapping** of key concepts through the application of the concentric circles model (Throsby, 2008), value chain models (European Commission, 2017; Li, 2020; Betzler & Leuschen, 2020), and the cultural cycle (UNESCO, 1986), in order to capture the full dynamics and development potential of the sector.

The paper explores the evolution of business models in the creative industries in the context of digital transformation and hybridization. New business models in the creative industry are emerging under the influence of digital transformation. These models take the form of hybrid models and appear as concentric circle models and value chain models.

2.1 The concentric circles model in the creative industries

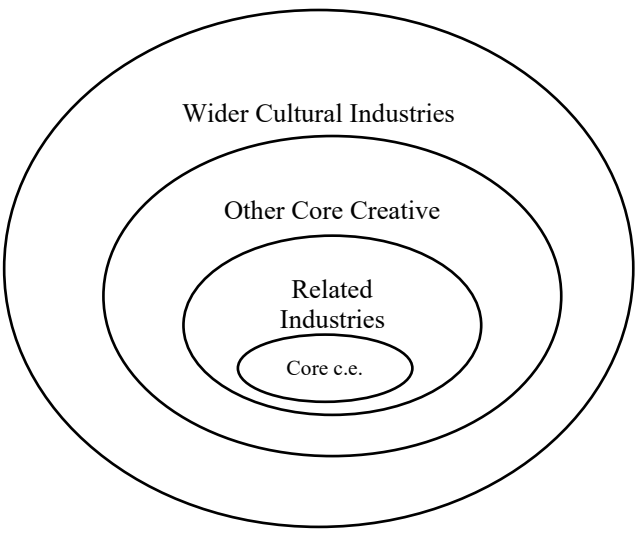
Numerous definitions of the creative industry point to its various aspects, ranging from the scope of the sector, key drivers, to the ways in which it is organized and structured (Throsby, 2001). The concentric circles model (CCM) represents a way of organizing and structuring creative and cultural industries and their subsectors (Throsby, 2008).

The concentric circle model is based on the division of the sector into core sectors and economic sectors (Graph 1). Core sectors include artistic and non-industrial activities, while economic sectors are connected to the core sector. The sectors are represented in the form of layers, and the further the layer is from the core sector, the less artistic or cultural content it contains. The core sector consists of three circles:

1) Core Cultural Expression, which as the first and core circle includes: Literature, Music, Performing Arts and Visual Arts,
2) Related Industries, which include: Advertising, Architecture, Design and Fashion,
3) Other Core Creative Industries, which include: Film, Museums, Galleries, Libraries and Photography.

The economic sector consists of:

4) Wider Cultural Industries, which include: Heritage Services, Publishing and Print, Media, Television and Radio, Sound Recording, Video and Computer Games.



Graph 1: The concentric circle model
Source: Throsby, 2008.

2.2 The value chain in creative industries

In addition to the concentric circle model, another framework that emphasizes the interdependence between creative industries and related sectors is the value chain model in creative industries.

The value chain encompasses the stages of creation, production, distribution, and consumption of cultural and creative goods and services. A distinction is made between the creative value chain and the economic value chain. The creative value chain begins with an initial creative concept and develops through a series of interconnected stages before reaching the end user (European Commission, 2017).

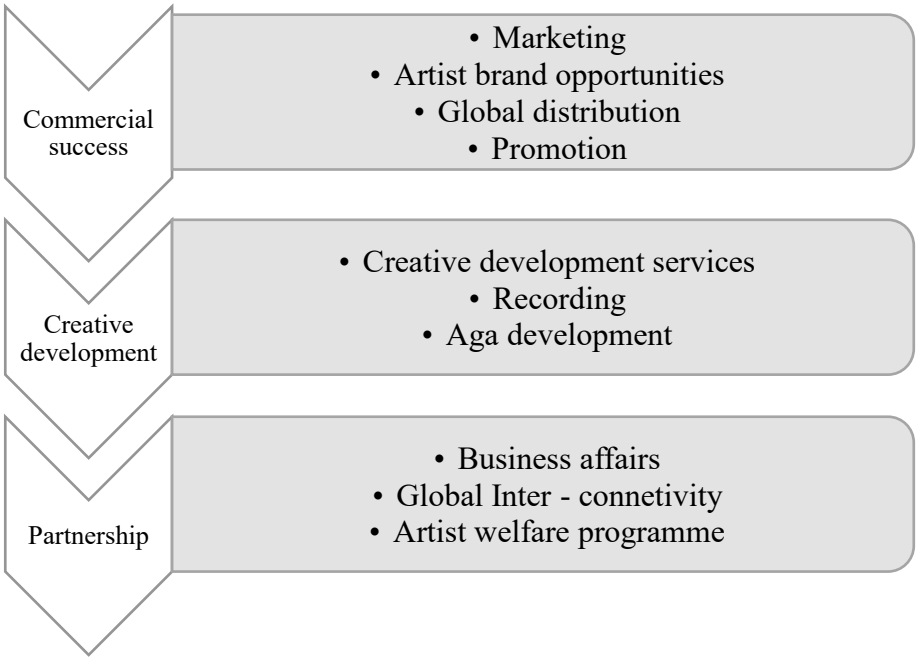
The economic value chain primarily involves tangible goods and is defined by core elements such as efficiency, specialization, a longer product life cycle, and a linear, vertically integrated structure. In contrast, the creative value chain is centered on intangible goods, with innovation and creativity at its core. It typically involves a shorter product life cycle and is characterized by interdisciplinary collaboration and partnerships in both the creation and distribution of creative content (Table 1).

Table 1: Differences between creative and economic value chains

Characteristics	Creative value chains	Economic value chains
Products vs. Services	Intagible goods such as ideas, intellectual property and artistic expressions	Tangible goods
Basic components	Innovation and creativity	Efficiency and specialization
Product life cycle	Shorter life cycle	Longer life cycle
Collaborative nature	Collaboration and networking	Linear and vertically integrated structure

Source: European Commission, 2017; GIZ 2024.

A value chain example in the music industry contains several related components that, in addition to creative development, include commercial success and parthership (Graph 2) (Global Music Report, 2024).



Graph 1. A value chain in the music industry
Source: author based on Global Music Report, 2024.

The concept of value creation in the creative industries is often articulated through the framework of the cultural cycle. The cultural cycle emphasizes the interconnected nature of activities that contribute to the development of new cultural products and services. According to UNESCO (1986), the cultural cycle consists of five key phases: creation, production, dissemination, exhibition (or transfer), and participation (or consumption):

1) Creation: Refers to the origination and authorship of ideas and content—such as the work of sculptors, writers, and design studios—as well as the production of one-of-a-kind works like fine art and artisanal crafts.
2) Production: Involves the replication of cultural forms, alongside the specialized tools, infrastructure, and processes needed to bring them to life.
3) Distribution: Encompasses the delivery of cultural goods to consumers and venues through wholesale and retail channels, rentals (e.g., of music or video games), film distribution, or digital platforms.

4) Exhibition/Reception/Transfer: Denotes the site or mode of cultural consumption, where audiences are granted access—either sold or facilitated—to experience cultural offerings within a set timeframe.
5) Consumption/Participation: Represents the active engagement of audiences in cultural practices, such as dancing, attending carnivals, listening to radio broadcasts, or visiting galleries.

Within both the creative value chain and the cultural cycle, the shaping of creative outputs is largely driven by diversification. Unlike traditional economic sectors that often rely on specialization, the creative industries—particularly in developing countries—frequently lack the necessary market demand and resources to support narrow specialization. As a result, creative enterprises tend to diversify their offerings and adjust to market needs in order to survive and grow (e.g., music distribution expanding into audiovisual content development).

In contrast to the economic value chain, which is primarily commercial in nature, the cultural value chain also includes non-commercial transfers, such as the passing down of intangible cultural heritage across generations. UNESCO member states utilize the concept of the cultural cycle to conceptualize cultural production and to address challenges related to building a resilient and sustainable cultural ecosystem (UNESCO, 2009).

3 Collaboration as a feature of business models of creative industries: advantages and disadvantages

The collaborative nature is one of the key characteristics of business models and value chains in creative industries. Creative industries often rely on co-production schemes and strategic partnerships to generate greater synergy, which also includes the development of payment facilitation mechanisms to stimulate digital demand and enhance market penetration (ITC, 2019):

1) A synergistic approach that integrates digital and analog promotion

The rise of new technologies and digitalization has led to the emergence of value-added services on streaming platforms. Machine learning algorithms analyze user behavior during content consumption and generate personalized recommendations.

This demonstrates that artificial intelligence and human expertise can complement each other within the creative sector, aligning with the EU's General Code of Conduct for Artificial Intelligence under the EU AI Act (EU, 2024).

2) Partnerships with telecommunications operators as a sustainable business model

Telecom operators increasingly act as content providers, forming mutually beneficial collaborations with creative industries. One notable model involves Telecom companies producing musical content for ringtones—music that plays before a call is answered—replacing traditional call tones. This partnership expands the music industry's reach, connecting artists and fans across multiple platforms and revenue streams, whether through direct cooperation with digital services or through record labels. As this segment evolves, overall compensation for artists is expected to increase (Anantrasirichai & Bull, 2021; Arshad et al., 2025; Villerment et al., 2021).

3) Payment facilitation as a key driver of digital demand

Limited payment options for creative products hinder market expansion. Therefore, developing accessible online payment systems is essential. Streaming services should incorporate payment models in local currencies and allow users to make purchases using mobile credits. Another promising method is direct user donations to artists, offering a more personal way to support creative work. Many creators already utilize platforms that enable followers to contribute financially and sustain their projects.

4) Mobile penetration and digital access in the creative industry

The rapid increase in mobile device usage and digital platform adoption has opened up new markets for creative content. Over the past decade, the number of global internet users has nearly doubled, significantly contributing to the growth of digital products and services within creative industries (World Bank, 2024). Collaboration with digital platforms helps creators establish a presence more quickly, build a fan base, and generate revenue from sources like concert tickets, branded merchandise, and digital media.

While collaboration brings numerous advantages, such as reduced distribution costs, broader audience access, and increased innovation, there are also significant challenges, including:

1) A low level of hybridization in certain business models, and
2) Value gaps resulting from unequal distribution of profits between digital platforms and creative sectors.

Hybridization of economic models in the creative and cultural industries involves combining multiple sources of income and funding. When digitalization is paired with hybridization, it typically leads to positive outcomes by expanding monetization strategies and content accessibility. In general, digitalized sectors tend to be hybridized—exceptions include some segments of the music and publishing industries. A high Hybridization index indicates diverse income streams. For example, the video game industry has six major revenue channels: physical/digital sales, subscriptions, paymium (free-to-play with paid features), advertising, and microtransactions. In contrast, a low hybridization index in the book industry reflects a more limited range of monetization options (Salmon, 2015) (Table 2).

Table 2: Digitalization rate and Hybridization indeks

Content	Video games	Music	Movies	Books
Digitalization rate	72	50	30	15
Hybridization index	80	41	56	23

Source: Salmon, 2015

The relationship between hybridization and digitalization across various cultural sectors can be illustrated as follows (Salmon, 2015):

1) Video games: High level of hybridization, featuring a broad range of economic models.
2) Music: Moderate hybridization, characterized by a mix of payment systems and streaming platforms.
3) Film: Low hybridization, though digitalization is on the rise.
4) Books: Very low hybridization, still largely dependent on traditional sales models.

In sectors with low levels of hybridization, creative industries can combine traditional and digital business models to drive growth—for example, by selling concert tickets online or offering hybrid formats of cultural experiences.

A major challenge facing creative industries today is the fair distribution of revenue, which is crucial for ensuring their long-term sustainability. The intricate network of stakeholders—artists, creators, producers, distributors, and others—often lacks sufficient bargaining power when compared to global digital platforms and content distribution networks that dominate the market.

According to the International Federation of the Phonographic Industry (IFPI), in 2015, Spotify paid an average of $20 per user annually to music rights holders, while YouTube returned less than $1 per user to content creators. While 900 million users of user-generated music content platforms generated around $553 million, 212 million paid or ad-supported users contributed nearly $4 billion in revenue (IFPI, 2017).

This disparity reflects the broader issue of content devaluation—the growing gap between the value extracted by user-generated content platforms like YouTube and the revenue returned to the music ecosystem, including artists, producers, and investors. The European Commission has acknowledged this "value gap" as a form of market distortion, emphasizing the need for regulatory intervention to address the imbalance (EU, 2017).

4 Creative industry and agenda 2030

In relation to the contribution of creative industries to achieving the 2030 Agenda, several strategic documents have been established that link this sector to the Sustainable Development Goals (SDGs). The potential of the creative industry to foster sustainable and inclusive growth led to the adoption of the UN Resolution on the Creative Economy in 2020. As a result of this resolution, 2021 was designated as the International Year of the Creative Economy.

Moreover, the creative economy is increasingly recognized for its capacity to support the implementation of the 2030 Agenda, even though the Agenda does not include a specific goal dedicated solely to culture or the creative industries (Creative

Economy 2030: Inclusive and Resilient Creative Economy for Sustainable Development and Recovery, 2021). Cultural and creative industries are most directly connected to SDG 8, which promotes sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all; and SDG 12, which focuses on ensuring sustainable consumption and production patterns, including cultural dimensions.

Under the UNESCO Culture 2030 Indicators initiative, 22 indicators have been developed to demonstrate the interconnections between culture, the creative economy, and the SDGs (Table 3) (UNESCO, 2019; Larasati & Satari, 2021). Culture contributes to the SDGs both as a standalone sector and as an integral component of other development areas. Accordingly, it plays a role in advancing goals related to sustainable cities, economic growth, social inclusion, environmental protection, and more. Conversely, the economic, social, and environmental dimensions of sustainable development also reinforce efforts to preserve cultural heritage and promote creativity.

Table 3: Relationship between the Culture 2030 Indicators and SDGs

Transversal thematic dimensions	The Culture 2030 Indicators	SDGs
Environment & Resilience	1) Expenditure on heritage	SDG2: Zero hunger SDG6: Clean water and sanitation SDG11: Sustainable cities and communities SDG12: Responsible consumption and production SDG13: Climate action SDG14: Life below water SDG15: Life on land SDG16: Peace, justice and strong institutions
	2) Sustainable management of heritage	
	3) Climate adaptation & resilience	
	4) Cultural facilities	
	5) Open space for culture	
Prosperity & Livelihoods	6) Culture in GDP	SDG8: Decent work and economic growth SDG10: Reduced inequalities SDG11: Sustainable cities and communities
	7) Cultural employment	
	8) Cultural businesses	
	9) Household expenditure	
	10) Trade in cultural goods & services	
	11) Public finance for culture	
	12) Governance of culture	
Knowledge & Skills	13) Education for Sustainable Development	SDG4: Quality education SDG8: Decent work and economic growth
	14) Cultural knowledge	

Transversal thematic dimensions	The Culture 2030 Indicators	SDGs
	15) Multilingual education	SDG9: Industry, innovation and infrastructure SDG12: Responsible consumption and production SDG13: Climate action
	16) Cultural & artistic education	
	17) Cultural training	
Inclusion & Participation	18) Culture for social cohesion	SDG9: Industry, innovation and infrastructure SDG10: Reduced inequalities SDG11: Sustainable cities and communities SDG16: Peace, justice and strong institutions
	19) Artistic freedom	
	20) Access to culture	
	21) Cultural participation	
	22) Participatory processes	

Source: UNESCO, 2019.

The connection between digital and hybrid business models in the creative industry and their contribution can be viewed in the direction of achieving SDG:13, as well as, other related SDGs. Considering that SDG 13 is part of two cross-cutting thematic areas Culture 2030, the impact on reducing carbon dioxide emissions will be significant.

4.1 New Business Models in the Creative Industries: Key Recommendations

The paper highlights the following key insights and recommendations:

1) The transformation of business models through digitalization fosters the emergence of hybrid models that combine different revenue sources, distribution channels, and forms of collaboration (e.g., partnerships with telecom operators, direct donations from users).

Digital collaboration and platforms create new forms of value but also present challenges, such as, unequal revenue distribution and a low degree of hybridization in certain sectors. Hybrid models represent a potential for bridging the gap between large digital platforms and small creative businesses, fostering a more balanced cultural development.

2) The use of the cultural cycle enables viewing creative production as a dynamic and multi-phase process that, also, includes intangible values,

which has significant implications for preserving cultural identity and local creative economies.

3) Creative industries as a transversal actor in achieving the Sustainable Development Goals (Agenda 2030), with a particular focus on contributing to SDG 8 (decent work and economic growth) and SDG 12 (sustainable consumption and production). The connection with the 2030 Agenda is reflected in the contribution of the creative industries to economic growth, inclusion, digital literacy, and the preservation of cultural identity.
4) The proposed analytical approach and identified recommendations can serve as a basis for developing strategies that promote fairer value distribution in the digital environment, strengthen institutional support for small creative businesses, and shape inclusive cultural policies. Further research should focus on developing quantitative models to measure the impact of new business models on sustainability, as well as on mapping the challenges faced by small creative firms in the digital age.

5 Conclusion

The paper builds upon the concentric circles model, emphasizing the pivotal role of the creative industries in driving growth and innovation across various sectors of the economy. Digital transformation, far from diminishing the relevance of business models in the creative sector, has acted as a catalyst for their evolution. Contemporary business models are increasingly structured around value chains that underline sectoral interconnectedness, strategic partnerships, and the development of digital functionalities.

There are differences between economic and creative value flows, which determine the direction of development in creative industries. Diversification and collaboration enable the creative industries sector to adapt to changing business conditions. Moreover, new hybrid business models are being developed, characterized by greater diversification in terms of revenue sources. A higher level of digitalization should be followed by a higher degree of hybridization. However, there is a part of the creative industries characterized by lower levels of diversification, which gives the industry the possibility of combining traditional and digital payment sources. Additionally, market distortion in the form of gaps in the unequal distribution of value will need to be addressed with a stronger institutional framework in the EU.

The relationship between the creative industry and the 2030 Agenda is described as transversal, but it can also be viewed in the context of concentric circles, as the contribution exists but is not the same across all segments of the industry. Digital business models and the ongoing transition of creative industry operations to digital platforms are poised to significantly contribute to the sustainable transition. Additionally, within the cultural industry, principles and areas have been developed that should contribute to the achievement of the SDGs. Twenty-two principles have been defined within four thematic areas as support for the culture sector in inclusive and sustainable development. Digital business models in the creative industry, and the transfer of business activities to digital platforms, will greatly contribute to the achievement of the sustainable transition and SDGs, especially SDG 13, the quantification of which is expected in the future.

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The Role of Universities in Sustainable Transformation

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Achieving academic excellence requires exceptional dedication, long-term work, and continuous education. The synergy with new techniques, technologies, and trends, the dissemination of knowledge, the development of new curricula, and universities as drivers of innovation are part of the helix model. Universities should provide knowledge and contribute to the development of skills for applying digital transformation and AI. Education for sustainable development should be one of the main priorities in line with SDG 4, which focuses on quality education. The objectives of the research in this paper are:

1. The significance of universities and the key components of their contribution to achieving the SDGs,
2. The contribution of universities to achieving SDG 4, and
3. A comparative analysis of implemented activities and programs that promote learning about sustainable development and digital transformation: Faculty of Contemporary Arts, Serbia, and Faculty of Economics and Business, Maribor.

The methodological framework of the research is based on a qualitative approach through the use of a case study, which enables an in-depth analysis of educational practices and management strategies, in the context of education for sustainable development within specific higher education institutions.

Keywords:
university,
education,
sustainability,
quality education,
SDG

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1 Introduction

The concept of sustainability is often narrowly interpreted as solely environmental sustainability. However, in alignment with the Sustainable Development Goals (SDGs), it is essential to adopt a broader understanding that encompasses economic, social, and societal dimensions.

The SDGs and the Agenda of sustainable development present a unique opportunity for all stakeholders—both nationally and globally—to actively contribute to a more sustainable future. Within this framework, the social responsibility of higher education institutions (HEIs) plays a pivotal role in driving the transition towards sustainability. From an institutional perspective, universities are uniquely positioned to develop innovative educational approaches that foster interdisciplinary and inclusive learning while addressing pressing global challenges.

Education has been recognized as one of the most powerful tools for tackling the sustainable development challenges that have emerged throughout the 20th century, including climate change, poverty, and inequality (Lutz et al., 2014). In this regard, universities contribute significantly to the SDGs, particularly SDG 4, which emphasizes that education should ensure all learners acquire the knowledge and skills necessary to promote sustainable development (UN, 2015). The role of education is thus to provide inclusive, high-quality learning opportunities while fostering lifelong learning.

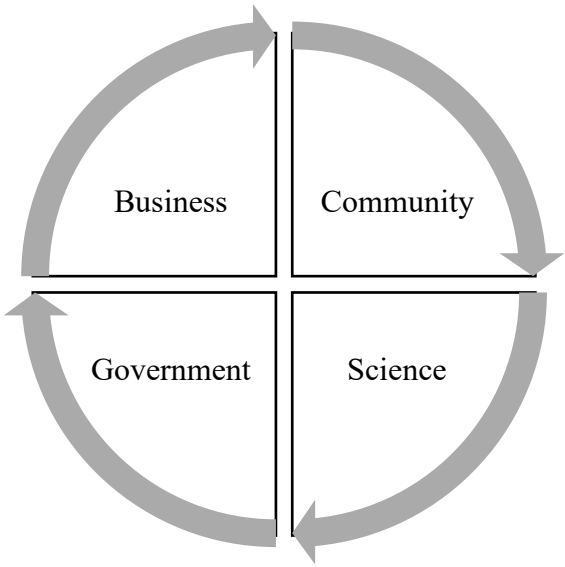
Universities are increasingly designing curricula and cultivating educational cultures that align with and advance the achievement of the SDGs. This transformation of educational curricula is occurring through multiple stages and represents a foundational aspect of a new educational culture within higher education.

Higher education institutions such as the Faculty of Economics and Business (University of Maribor) and the Faculty of Contemporary Arts (Belgrade) exemplify how higher education can contribute to the realization of the SDGs through quality education and innovative academic practices.

2 Universities as drivers of sustainable education and achieving SDGS

The role of universities as key drivers and agenda-setters in sustainable development has been recognized in numerous documents, strategies, and tools for promoting progress. Educational innovations include collaboration with all relevant stakeholders, the development of strategies for curriculum changes, institutional and educational leadership, and the creation of a sustainable institutional culture. Transformative changes occur within paradigms based on repeated and dynamic interactions between all actors.

The quadruple helix model highlights the importance of science and universities in the societal system, while an irregular spiral approach shows how sustainable science can be encouraged by involving all interested stakeholders. The quadruple helix model recognizes the key change agents in four spheres: business, community, government, and science (Carayannis & Campbell, 2009) (Graph 1).



Graph 1. The quadruple helix model
Source: Carayannis & Campbell, 2009.

According to the quadruple helix model, the key stakeholders in these four areas are:

- Business: Local enterpreneurs and National and international corporations,
- Community: Citizens, Professional asociations, Interest groups and NGOs,
- Government: Local, Regional and Nacional and
- Science: Universities, Think tanks and Other knowledge producers.

The tool for implementing sustainability science and involving all relevant stakeholders can be based on an irregular spiral approach, which shows how to transform the current society into a future sustainable society by repeating five basic steps (Boehm, 2000):

1. Co-realization of a common problem
2. Co-envisioning futures
3. Co-shaping into envisioned future society
4. Co-implementation and
5. Monitoring and evaluation.

The downside of the spiral model is that it does not identify key holders of educational integration, but it emphasizes the importance of collaboration and integration towards the future sustainable transformation of society.

In the context of sustainable development, universities are expected to provide institutional and educational leadership. Academic professors think beyond traditional frameworks, applying problem-based and project-based teaching, and facilitating the transformation process. In such an environment, students learn to conceptualize, design, implement, and manage projects (Crawley et al., 2014). A transition higher institution into a sustainable higher institution goes through the following phases (Galán-Muros, 2023):

- Stage 0: Conceptual alignment and rationale
- Stage 1: Awareness raising
- Stage 2: Leadership commitment
- Stage 3: Stakeholders engagement
- Stage 4: Strategy design and draft

- Stage 5: Knowledge provision
- Stage 6: Current initiatives mapping
- Stage 7: Future initiatives prioritization
- Stage 8: Resources provision
- Stage 9: Implementation and
- Stage 10: Long-term sustainability.

This model, like the previous, emphasizes the need for institutional change within the university during its transition to sustainability. Additionally, the model highlights the importance of top leadership at the university, which will be a crucial factor in driving the transition to a sustainable model. The concept of sustainability becomes a shared value among leaders and all employees, and its development is based on the principle of continuity. The change in the teaching curriculum is also an important part of the university's transformation, and according to this model, it refers to the design of programs and courses related to the SDGs, as well as, the training of teachers on how to integrate the SDGs into their teaching.

The model distinguishes three types of sustainability that universities should consider when developing and implementing projects related to the transition to a sustainable university: financial sustainability, sustainable business and organizational sustainability.

Financial sustainability is achieved when a university's sustainable transformation project continues to operate after the planned end date by utilizing new sources of funding. Sustainable business refers to the continuation of the project beyond its planned conclusion, thanks to the new sources of income generated by the project. Organizational sustainability represents the day-to-day functioning of the implemented solution, which continues to operate even after the project ends.

To achieve these forms of sustainability, it is necessary to create a long-term sustainability plan, find new sources of funding, and integrate sustainable practices into the university's everyday operations.

3 Teaching models and strategies contributing to sustainable development in universities

New innovative educational solutions emerge as a result of the transformative change in higher education. These new educational solutions are the outcome of the synergistic effect of changes within universities related to curriculum adjustments and global changes driven by the development of education for sustainable development.

Within universities, changes in educational culture and the understanding of learning take place, with curriculum revision at the heart of these transformations. This process requires a strategic approach through strategies of addition, integration, and reconstruction (Kolmos et al., 2016).

The "addition" strategy involves incorporating more active learning into existing courses. It is the most common approach for transitioning to student-centered learning, evident through active learning strategies at the course and lecture levels in both literature and practice. The "integration" strategy connects existing courses with skills and competencies related to project management, collaboration, and strategic curriculum change. The "reconstruction" strategy refers to restructuring at the systemic level by establishing new institutions or programs that include technical knowledge and professional competencies. This approach facilitates all forms of active learning, including open-ended projects.

Globally, the implementation of the 2030 Agenda and the pursuit of quality education have accelerated the advancement of Education for Sustainable Development (ESD) (UNESCO, 2019). ESD promotes actions aimed at fostering a more sustainable world by encouraging inquiry and empowering individuals to adopt sustainable practices (Tilbury & Wortman, 2004). Like the previously described models, ESD emphasizes the creation of curricula and learning environments that cultivate responsible and sustainability-oriented behavior in students.

Transformed learning models now include active classroom engagement, as well as, problem- and project-based learning. These models combine online and face-to-face instruction, incorporating active learning techniques to enhance student engagement. Practice-oriented learning often involves problem-and project-based

learning and includes professional practice, industry projects, entrepreneurship, and innovation hubs. Supporting structures such as: formal training programs, user forums, mentoring, and implementing mentoring programs and individual coaching, play a key role in facilitating the transition of universities toward sustainability.

The model based on the integration of engineering and technology emphasizes the critical role of these two elements in achieving the SDGs (UNESCO, 2010). In Sweden, higher education policy mandates that engineering students acquire knowledge and competencies related to sustainabilitys (Holgaard et al., 2016).

Universities worldwide are actively developing initiatives aligned with to education for sustainable development. At Aalborg University, megaprojects hhave been implemented to address sustainability challenges through project-based learning. Drawing on a multidisciplinary approach to solving sustainable development challenges, students collaborate on a single sustainability issue, such as addressing household waste, but each contributes from their own discipline (Routhe et al., 2020).

At the National University of Colombia, the PEAMA program (Special Program for Admission and Academic Mobility) was created to improve access to higher education in rural and underprivileged communities and to support better performance on entrance exams. The four-semester program covers areas such as nursing, agricultural engineering, agronomy, veterinary medicine, and animal science.

In line with the university's commitment to sustainable transition and achieving the SDGs, a program has been developed SET4HEI, as an online free self-assessment tool that allows institution to measure their contribution to each of the 17 SDGs based on a a framework of 400 potential activities categorized across four dimensions: Teaching and Learning, Research, Engagement, and Governance & Administration (Galán-Muros, 2023).

3.1 Key recommendations for enhancing the management of ESD

The governance of ESD entails practical actions supported by integrating sustainability into a university's mission and vision, developing interdisciplinary curricula, building the capacities of educators and students, and fostering

collaboration with local communities, businesses, and global initiatives (UNESCO, 2010; UNESCO, 2019; Tilbury & Wortman, 2004; Kolmos et al., 2016):

1) Integrate sustainability into the university's mission and vision.
ESD should be embedded within institutional strategic planning and policymaking, leading to the development of comprehensive action plans that engage all sectors—teaching, research, and campus operations—reflecting a model of responsible and holistic governance.

2) Develop interdisciplinary curricula.
Institutions should revise existing curricula to incorporate topics such as climate change, ethics, and the circular economy, while also designing new programs and modules that merge multiple disciplines, fostering systems thinking and cross-sectoral competencies.

3) Strengthen institutional capacity and build educator competencies for ESD.
This includes providing professional development opportunities and training for faculty to effectively deliver sustainability education. Promoting active learning and student engagement supports the development of critical thinking and problem-solving skills through tackling real-world sustainability challenges.

4) Foster collaboration with local communities and sustainability-oriented businesses.
ESD should include partnerships with local stakeholders to facilitate knowledge exchange and practical application. In addition, educational institutions are encouraged to participate in global initiatives that support the achievement of the Sustainable Development Goals (SDGs).

4 Contributions faculty of economics and business and faculty of contemporary arts to the SDGS

Faculty of Economics and Business (Maribor) and Faculty of Contemporary Arts (Belgrade) are higher education institutions with different study programs. However, both institutions are dedicated to ESD and, through different activities, contribute to the achievement of the SDGs, particularly SDG 4. Below is an analysis of one selected activity from each institution: Intensive programme: Sustinablility in

International Business (Faculty of Economics and Business) and Global Education Week (Faculty of Contemporary Arts).

The Faculty of Economics and Business is dedicated to education and organized the Erasmus Blended Intensive Program: Sustainability in International Business, held in 2022 and 2023 (EPFM, 2023). The program combined theoretical lessons (lectures and workshops) with a practical approach (visits to the Primorska region, discussions, and analyses) to highlight the concept of sustainability in international business and create conditions for building long-term sustainable and resilient socio-economic environments. The program presented methods for implementing sustainability into the business models of 14 companies, making a significant contribution to the Faculty of Economics and Business's ESD.

The multiple benefits and significance of the educational, business, and social approach of the Sustainability in International Business program are:

- Defined key themes of the program in line with ESD,
- Significant themes from the perspective of future opportunities and cooperation with other institutions: Concepts of sustainable international business; Sustainability in the value chain; Sustainability in international marketing; Sustainability in international supply chains,
- Key themes for the development of new projects: Concepts of international business; Benefits and challenges of implementing sustainability in international business operations,
- Key themes for the academic community: Promoters of sustainable development; Green transformation as a sustainable practice in international business; The problem of "greenwashing" and the importance of consumer awareness; ESG reporting standards and reporting challenges; Future perspectives of sustainable development and sustainable business; Digitalization as a sustainable practice in international business; Approaches and models for measuring sustainable business,
- Key topics for students in building an academic career: The concept and importance of sustainable development; The concept of sustainability; Economic, ecological, and social actors of sustainable business; Benefits and challenges of implementing sustainability in international business operations; Sustainability in the value chain; Examples of best practices in

sustainable business by multinational companies; The impact of sustainability on global competitiveness; Recognizing transformational levers in business activities or corporate models in the context of sustainability.

- Applicability of the program framework for the Faculty's future activities and
- The program's best practice example as an encouragement for other higher education institutions to plan and implement similar activities.

Faculty of Contemporary Arts contributes to numerous curricular and extracurricular activities to achieve Agenda 2030. In addition to the partnership with the New European Bauhaus, in 2024, it was the only partner higher education institution from Serbia, Global Education. The Global Education Week, as a program of Global Education of the Council of Europe, was developed specifically to raise awareness about global issues and promote global education as a key tool for fostering solidarity, intercultural dialogue and sustainable development.

In the Global Education Week 2024, the Faculty participated with two activities: "Digital marketing in the function of promoting global education" and "Education for sustainable development through the prism of multimedia production". Students of MAS Creative Industries and MAS Management of Creative Industries participated in the first activity. Students of the fourth year of BA Multimedia production, participated in the activity "Education for sustainable development through the prism of multimedia production". In addition to educational outcomes, these activities are examples of encouraging young people through collaborative learning to creativity and innovation, which improve the quality of education.

5 Conclusions

The paper presents the role of higher education in achieving the SDGs. Significant efforts are being made to build sustainability as part of the institutional environment of contemporary universities. This institutional environment implies the transformation of curricula and teaching organization toward the application of more active methods, problem-based, project-based, and collaborative teaching. Universities contribute to the achievement of SDG4: Quality Education, by

modernizing teaching and preparing students to address global challenges, fostering an educational culture, and creating educational innovations.

The paper presents the activities of two faculties, which serve as examples of good teaching and educational practices that can inspire other faculties. These examples demonstrate how higher education institutions can be at the forefront of achieving sustainable development goals, particularly SDG 4, by creating innovative educational approaches that tackle global issues while enhancing students' skills and competencies for the future**.**

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN ELIMINATING LANGUAGE AND CULTURAL BARRIERS IN CROSS-BORDER E-COMMERCE

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Cross-border e-commerce allows businesses to access international markets but faces significant language and cultural barriers. This study examines how artificial intelligence technologies overcome these challenges. Through literature review and case analyses, the study identifies major language barriers including translation quality and content creation, and cultural barriers such as design preferences and payment methods. The research demonstrates how AI applications like neural machine translation, culturally responsive recommendation systems, and AI-powered chatbots effectively address these challenges. Case studies for global platforms (Amazon, Alibaba, eBay) and SMEs reveal that the implementation of AI solutions has significantly increased international sales, dramatically improved translation accuracy and increased customer engagement. The findings suggest businesses should integrate AI into their internationalization strategies while maintaining human oversight and cultural sensitivity. This study contributes to understanding how AI transforms cross-border e-commerce by eliminating traditional barriers to global market entry.

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1 Introduction

In today's world where globalisation is increasing rapidly, developments in information and communication technologies have made it easier for businesses to access international markets by crossing geographical borders. Cross-border e-commerce has emerged as a business model that allows businesses to offer products and services to consumers in countries where they are not physically located through digital platforms (Li, 2019). With the COVID-19 pandemic, the global e-commerce volume has shown a significant increase and reached 5.7 trillion dollars in 2022 (UNCTAD, 2023). This growth is expected to continue in the coming years.

Despite the vast opportunities offered by cross-border e-commerce, businesses face various challenges when operating in this area. Language and cultural barriers are among these challenges (Wang & Yang, 2020). The need to create content in different languages, provide customer service, and develop marketing strategies in line with local cultural characteristics pose significant barriers, especially for small and medium-sized enterprises (Hsiao et al., 2018).

Artificial intelligence technologies offer new opportunities to overcome these barriers. AI applications such as natural language processing, machine learning and computer vision allow businesses to automate and optimise translation, content creation, customer service and cultural adaptation processes (Davenport et al., 2020). While these technologies enable businesses to operate more efficiently and effectively in global markets, they also enable consumers to have a shopping experience in their own language and in accordance with their cultural preferences.

The purpose of this study is to examine the role of artificial intelligence in eliminating language and cultural barriers in cross-border e-commerce and to evaluate successful applications in this field. The study seeks answers to the following research questions:

i. What are the main language and cultural barriers faced by businesses in cross-border e-commerce?
ii. What role do AI technologies play in overcoming these barriers?
iii. What are successful AI applications in overcoming language and cultural barriers?

iv. What are the challenges and solutions that businesses face in adopting AI-enabled solutions?

This study aims to provide a comprehensive perspective for businesses, policy makers and researchers operating in cross-border e-commerce. In this context, the study follows a structure where first, the concept, development and current status of cross-border e-commerce will be analyzed, followed by examining the linguistic and cultural barriers faced by businesses. Then, the role of artificial intelligence in overcoming these barriers will be analyzed, with specific AI applications in cross-border e-commerce discussed through case studies.

2 Theoretical background and literature review

2.1 Cross-Border E-Commerce

Cross-border e-commerce involves commercial activities between buyers and sellers in different countries through electronic platforms (Gomez-Herrera et al., 2014). This model enables businesses to enter international markets at low costs. Its development is linked to technological advances, increased internet penetration, and improved logistics (Kawa & Zdrenka, 2016). McKinsey & Company (2022) projects global cross-border e-commerce to exceed $1 trillion by 2026, driven by digital technologies, smartphone usage, and interest in foreign products (Singh et al., 2020). This trade model offers consumers wider product ranges and competitive prices, while providing businesses revenue growth and market diversification (Kim et al., 2017). The COVID-19 pandemic further accelerated its importance (Bhatti et al., 2020).

2.2 Language and Cultural Barriers

Language barriers represent significant challenges in cross-border e-commerce, requiring businesses to provide website content, product information, and customer service in multiple languages (Cheng et al., 2019). Traditional translation methods can be costly and inadequate for conveying language nuances (Gefen & Carmel, 2008). Zhang and Dodgson (2021) note that language barriers affect market entry strategies, often limiting expansion to linguistically similar markets.

Cultural barriers significantly impact consumer behavior. Hofstede's (2001) cultural dimensions theory reveals how differences in individualism-collectivism, power distance, and other dimensions shape consumer preferences. De Mooij and Hofstede (2010) emphasize that cultural factors influence website design, visual elements, and communication style. Hall (1976) distinguishes between high context cultures (Japan, China) where visual elements and indirect communication prevail, and low context cultures (USA, Germany) preferring direct communication. Payment preferences also vary culturally (Capgemini, 2022).

2.3 Artificial Intelligence and E-Commerce

Artificial intelligence encompasses computer systems that mimic human intelligence (Russell & Norvig, 2020). In e-commerce, AI improves customer experience, operational efficiency, and strategic decision-making (Davenport et al., 2020). Gartner (2023) reports that 75% of e-commerce businesses plan to invest in AI technologies within three years, with significant focus on overcoming language and cultural barriers.

Natural language processing (NLP) technologies facilitate translation, sentiment analysis, and chatbot applications (Hirschberg & Manning, 2015). Advanced language models like Transformers and BERT provide context-sensitive translations (Devlin et al., 2019). Recommender systems analyze customer behavior and cultural preferences to offer personalized product recommendations (Schafer et al., 2007).

3 Methodology

This study employs a qualitative research approach combining comprehensive literature review with case study analysis to examine the role of AI in overcoming language and cultural barriers in cross-border e-commerce. The research methodology consists of two main components:

Literature Review: A systematic analysis of academic publications, industry reports, and market research studies focusing on cross-border e-commerce, language and cultural barriers, and artificial intelligence applications. Key databases and sources included academic journals in marketing, e-commerce, and technology fields, as well

as reports from organizations such as UNCTAD, Gartner, and McKinsey & Company.

Case Study Analysis: Multiple case studies were examined to provide empirical evidence of AI applications in cross-border e-commerce. The case selection followed a purposive sampling approach to include:

Global e-commerce platforms (Amazon, Alibaba, and eBay)

Small and medium-sized enterprises from different regions and sectors

Data for case studies were collected from company reports, industry analyses, and academic publications. The analysis focused on identifying AI technologies used, implementation strategies, and measurable outcomes in terms of international sales, customer satisfaction, and operational efficiency.

The data analysis process involved thematic analysis to identify patterns across different cases and literature sources. This methodological approach allowed for triangulation of findings from theoretical literature and practical applications, enhancing the validity and reliability of the research results.

4 Results

Research findings show that AI technologies play an important role in overcoming language and cultural barriers in cross-border e-commerce. The data obtained from literature studies and case analyses reveal that the implementation of AI-supported solutions has led to a a significant increase in international sales of businesses.

4.1 AI Applications in Overcoming Language Barriers

Neural machine translation (NMT) systems provide more natural and fluent translations using deep learning algorithms (Wu et al., 2016). These systems offer considerably higher translation accuracy and significantly faster translation speed compared to traditional translation methods (Martinez et al., 2022). They show superior performance especially in the translation of technical product descriptions and texts containing industry-specific terminology.

Businesses operating in the e-commerce sector use NMT systems to translate website content, product descriptions, customer reviews, and marketing materials. eBay's AI-assisted translation system allows sellers to automatically create product listings in different languages. Research shows that cross-border sales increased with the implementation of this system (Brynjolfsson et al., 2019).

Multilingual content creation and management systems automate the process of producing original content for different markets. AI-based content creation tools can produce content with appropriate tone, style and cultural references for a specific market (Kumar et al., 2021).

AI-powered chatbots and virtual assistants offer 24/7 support to customers in their own language. These systems have the capacity to understand customer inquiries, create appropriate responses, and direct them to human agents when necessary (Følstad and Brandtzæg, 2017). They can answer customer queries with high level of accuracy and reduce customer support costs by considerable improvement.

4.2 AI Applications in Overcoming Cultural Barriers

Culturally responsive recommendation systems provide personalised product recommendations by taking into account customers' cultural preferences, values and shopping behaviour. These systems increase customer engagement rates by 25% on average (Kumar et al., 2021).

Cultural adaptation of website and application interfaces is optimized through AI-supported A/B tests and user behaviour analyses. These analyses measure the impact of elements such as colour schemes, visuals, navigation structure and content layout on users from different cultures (Reinecke and Bernstein, 2013).

Cultural detection algorithms identify cultural sensitivities and potential cultural misunderstandings in marketing materials. By analysing how cultural elements such as symbols, colours and gestures in images are perceived in different markets, these algorithms prevent the publication of culturally inappropriate content (Johnson et al., 2018).

The optimization of payment methods and delivery options according to the cultural context is performed by AI algorithms. These algorithms analyse the preferred payment methods and delivery expectations in each market and offer the most suitable options (Capgemini, 2022).

4.3 Case Studies Findings

Global e-commerce platforms demonstrate significant success with AI implementations:

Amazon: Using AI Translate service for 55 languages and culturally-adapted recommendation algorithms resulted in a 22% increase in international revenues in 2022 (Amazon, 2023).

Alibaba: The ET Brain system offering real-time translation in 16 languages and AliMe chatbot increased customer satisfaction by 35% (Liu et al., 2020), enabling AliExpress to operate in more than 220 countries.

eBay: Implementation of AI-supported translation system increased cross-border sales by 17.5% in Latin America and 13.1% in Europe (Brynjolfsson et al., 2019).

SMEs also achieved remarkable results:

Wanderlust (Denmark): Using neural machine translation for 8 languages led to a 42% increase in international sales and 23% increase in customer satisfaction.

Naturali (Italy): AI-powered culturally-sensitive email marketing campaigns in 5 languages increased email open rates by 35% and conversion rates by 28%.

SnackWorld (Singapore): AI-powered cultural analysis system resulted in a 75% increase in international sales over two years.

5 Discussion

The findings of this study highlight several key insights about the role of AI in overcoming language and cultural barriers in cross-border e-commerce.

First, AI technologies demonstrate a clear positive impact on international sales, customer engagement, and operational efficiency. The consistent improvements across different sized businesses and diverse geographical regions suggest that AI applications have broad applicability in cross-border e-commerce, regardless of business scale or market context.

Second, the success of AI implementations depends significantly on several common factors identified across case studies. These include: (1) focus on data quality with high-quality and diverse training data; (2) continuous improvement with regular monitoring and refinement; (3) human-machine cooperation that balances automation with human oversight; (4) cultural sensitivity in system design; and (5) integration with existing business systems and processes.

Third, despite the promising results, businesses face significant challenges in adopting AI solutions. These include cost barriers (especially for SMEs), technical capacity limitations, data privacy concerns, and risks of cultural bias. The findings suggest that cloud-based AI services, industry-specific solutions, and training programs can help overcome these challenges. However, more research is needed on cost-effective AI implementation strategies for smaller businesses.

Fourth, the findings highlight the importance of an integrated approach to overcoming language and cultural barriers. Rather than viewing AI as a standalone solution, successful businesses integrate it into their broader internationalization strategies. This integrated approach allows for more effective adaptation to different market contexts.

Finally, the ethical implications of AI in cross-border e-commerce merit careful consideration. Issues of data privacy, algorithm transparency, and potential cultural biases in AI systems require attention from both businesses and policymakers. The long-term success of AI in cross-border e-commerce will depend on developing ethical frameworks and standards that build consumer trust.

6 Conclusıons

This study reveals that artificial intelligence (AI) technologies play an effective role in overcoming language and cultural barriers in cross-border e-commerce. AI applications such as neural machine translation, natural language processing, cultural analysis algorithms, and personalization systems enable businesses to reach consumers of different languages and cultures more effectively, significantly improving customer experience.

Research findings demonstrate that the implementation of AI-enabled solutions leads to notable improvements in international sales, customer satisfaction, and operational efficiency. These technologies particularly empower small and medium-sized enterprises (SMEs) to access global markets and gain competitive advantages.

However, several limitations must be acknowledged. First, the findings are primarily based on selected successful case studies, which may introduce a positive bias and limit the generalizability of the conclusions. Stronger statistical validations across broader datasets are necessary to confirm the observed impacts robustly. Additionally, AI-related risk factors—including data privacy breaches, algorithmic bias, and potential cultural homogenization—require thorough examination. Ethical concerns regarding transparency, fairness, and accountability also need to be systematically addressed.

When evaluating overall strategies, integrating language and cultural considerations into the broader business strategy is critical for maximizing the effectiveness of AI technologies in cross-border e-commerce. Prioritizing data quality, ensuring diverse and comprehensive datasets, and adopting hybrid models based on human-machine cooperation are vital for enhancing system performance and ensuring culturally sensitive adaptations.

Moreover, promoting SMEs' access to AI technologies through financial incentives, training programs, and technical support mechanisms will be essential to fostering digital transformation. Legal frameworks encouraging responsible data sharing and sectoral collaborations must balance innovation with data privacy and security protection. The development and international harmonization of ethical AI

frameworks, based on principles of transparency, fairness, and accountability, will play a crucial role in building sustainable, consumer-trusted digital economies.

Suggestions for future research include: (i) Examining the long-term effects of AI-supported language and culture solutions, (ii) Comparative analyses of AI applications in different sectors and markets, (iii) Developing new generation language models and cultural adaptation algorithms, (iv) Investigating ethical and privacy issues in AI technologies.

Artificial intelligence technologies offer revolutionary opportunities to eliminate traditional barriers in cross-border e-commerce. Their effective, ethical, and culturally sensitive use will be key to enhancing the global competitiveness of businesses and providing consumers with more personalized and locally resonant experiences.

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THE ROLE OF EXPERIENCE IN AI ADOPTION: THE MODERATING EFFECT ON PREDICTORS OF CHATGPT USAGE INTENTION AMONG GENERATION Z

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The objective of this study was to investigate the role of experience in the adoption of artificial intelligence (AI) tools, with a specific focus on its moderating effect on the predictors of ChatGPT usage intention among Generation Z in Croatia. The research employed the extended UTAUT2 model, examining crucial predictors such as Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Hedonic Motivation (HM), Price Value (PV), Habit (HT), and Personal Innovativeness (PI). The moderation analysis indicated that experience significantly moderates the effect of Habit (HT) on usage intention, ssuggesting that users with less experience tend to rely more on habitual usage. Furthermore, Social Influence (SI) displayed a marginally significant moderation effect, which suggests that less experienced users are somewhat more affected by social norms. Comparative analysis among the three experience level groups revealed significant differences in key predictors, thereby reinforcing the role of experience in shaping AI adoption behaviours. These findings underscore the significance of habit formation and social influence in the context of AI adoption, and they emphasize that strategies aimed at enhancing the adoption of AI tools should account for user experience levels.

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1 Introduction

The rapid adoption of AI tools, particularly generative AI like ChatGPT, is reshaping digital interactions and work environments. ChatGPT, one of the most widely used AI applications, has gained significant traction among Generation Z due to its versatility in generating human-like responses across various domains (Paul et al., 2023). While existing studies have explored factors influencing AI adoption using the UTAUT2 model (Venkatesh et al., 2012), limited research has examined the moderating role of experience in shaping these relationships. This study addresses this gap by analysing how user experience influences the predictors of ChatGPT adoption among Generation Z in Croatia. Building on previous findings that identified habit (HT), performance expectancy (PE), hedonic motivation (HM), and social influence (SI) as key drivers of adoption (Biloš & Budimir, 2024; Strzelecki, 2023; Nikolopoulou et al., 2020), this research investigates whether these effects vary depending on users' prior engagement with AI technologies. By applying moderation analysis, the study provides insights into whether beginners, intermediate users, and experienced users exhibit different behavioural patterns in AI adoption. Understanding these differences is crucial for businesses, educators, and policymakers aiming to optimize AI-driven solutions for diverse user segments. The findings contribute to the ongoing discussion on AI acceptance by highlighting experience as a key contextual factor in technology adoption.

2 Theoretical Background

The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) is one of the most comprehensive models for explaining technology adoption, expanding on the original UTAUT by incorporating consumer-centric variables (Venkatesh et al., 2012). The model includes performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), price value (PV), and habit (HT) as key determinants of behavioural intention (BI) and actual usage (USE). Numerous studies have validated UTAUT2 in different technology contexts, demonstrating that habit, performance expectancy, social influence, and hedonic motivation are among the most significant predictors of adoption (Strzelecki, 2023; Nikolopoulou et al., 2020; Cabrera-Sánchez et al., 2021; Garcia de Blanes Sebastian et al., 2022). In the context of AI-powered applications, recent research has explored factors influencing the adoption of chatbots and

generative AI tools such as ChatGPT. Paul et al. (2023) highlighted how AI-based chatbots enhance productivity and information retrieval, while Sugumar and Chandra (2021) emphasized the role of effort expectancy and perceived usefulness in AI adoption. However, existing studies typically analyse these predictors in a generalized manner, assuming their influence is uniform across all user groups. This approach overlooks, to some extent, that experience is crucial in shaping user perceptions and behavioural patterns in AI adoption.

Experience, defined as the extent to which users have interacted with a technology over time, has long been recognized as an important moderating factor in technology acceptance models (Venkatesh et al., 2003). The Technology Acceptance Model 3 (TAM3) explicitly included experience as a moderator of perceived ease of use and behavioural intention (Venkatesh & Bala, 2008), while later studies confirmed that experienced users develop automatic behavioural patterns, relying more on habit (HT) and intrinsic motivation (HM) than on external factors such as social influence (SI) or facilitating conditions (FC) (Cintron, 2022; Xian, 2021). Conversely, less experienced users are more likely to be influenced by social norms (SI) and perceived ease of use (EE), as they require external validation and support to build confidence in new technologies (Cabrera-Sánchez et al., 2021; Alalwan et al., 2017).

This study builds on these insights by examining experience as a moderating variable in the adoption of ChatGPT among Generation Z in Croatia. By investigating how experience influences the strength of relationships between UTAUT2 predictors and behavioural intention, this research aims to fill a critical gap in AI adoption literature. The findings will contribute to a deeper understanding of how different user segments interact with AI, offering practical insights for developers, businesses, and educators seeking to optimize AI-driven solutions based on user experience levels.

3 Methodology

This study employs a quantitative research approach using survey-based data collection to analyse the moderating effect of experience on the predictors of ChatGPT adoption. The research follows the extended UTAUT2 model (Venkatesh et al., 2012; Gansser & Reich, 2021), incorporating performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), price value (PV), habit (HT), and personal innovativeness (PI) as

independent variables influencing behavioural intention (BI). Experience is examined as a moderating variable, categorizing users into three groups:

- Beginners (tried ChatGPT but used it for less than a month),
- Intermediate users (used ChatGPT for more than a month but less than three months),
- Experienced users (used ChatGPT for more than three months).

The data was collected using an online survey distributed via the Alchemer platform, targeting Generation Z respondents (born 1997–2010) in Croatia. A total of 1,159 responses were collected, of which 694 valid responses were retained for analysis after removing incomplete and disqualified responses. The sample consists of 43.7% females and 56.3% males, with 50.7% being students, 29.1% balancing study and work, and 13.8% employed full-time. ChatGPT experience levels include 45.1% beginners, 36.0% intermediate users, and 18.9% experienced users. The survey instrument was adapted from previous UTAUT2-based studies (Venkatesh et al., 2012; Gansser & Reich, 2021) and measured all constructs using a seven-point Likert scale (1 = "strongly disagree" to 7 = "strongly agree"). The PE, EE, SI, FC, HM, PV, HT, PI, and BI survey items were based on validated scales used in AI adoption research (Garcia de Blanes Sebastian et al., 2022; Strzelecki, 2023). The study employed several statistical techniques to ensure validity and reliability. Confirmatory Factor Analysis (CFA) is used to verify construct validity and factor structure, and Hierarchical Linear Regression (HLR) is used to examine the direct effects of UTAUT2 predictors on BI. Moderation Analysis was employed to test whether experience significantly moderates predictor relationships with BI, while Cronbach's alpha and composite reliability (CR) were used to assess the internal consistency of constructs. All statistical analyses were conducted using JASP and Jamovi (JASP Team, 2022; The Jamovi Project, 2022).

4 Results

The dataset consists of 694 valid responses from Generation Z users in Croatia. Table 1 (Appendix) presents the means, standard deviations, and reliability measures (Cronbach's alpha) for the main study variables. All constructs demonstrated high internal consistency (Cronbach's $\alpha > 0.75$), confirming their reliability. The CFA

results indicated a good model fit ($\chi^2 = 1339.26$, df = 398, $p < 0.001$; CFI = 0.935; TLI = 0.924; RMSEA = 0.058; SRMR = 0.063). The factor loadings for all items exceeded 0.60, supporting construct validity. A hierarchical linear regression (HLR) was performed to test the direct effects of UTAUT2 predictors on behavioural intention (BI). The model explained 65% of the variance in BI ($R^2 = 0.65$, $p < 0.001$). The significant predictors were: Habit (HT, $\beta = 0.409$, $p < 0.001$), Performance Expectancy (PE, $\beta = 0.341$, $p < 0.001$), Hedonic Motivation (HM, $\beta = 0.243$, $p < 0.001$), Social Influence (SI, $\beta = 0.117$, $p < 0.001$) and Personal Innovativeness (PI, $\beta = 0.091$, $p < 0.001$). Non-significant predictors included Effort Expectancy (EE, $p = 0.961$), Facilitating Conditions (FC, $p = 0.652$), and Price Value (PV, $p = 0.561$).

Interaction elements were included in the regression model to examine whether experience moderates the relationships between UTAUT2 predictors and BI. The key findings include:

- Habit (HT) × Experience (estimate = -0.077, $p = 0.034$) → significant interaction, indicating that more experienced users rely less on habitual use than beginners;
- Social Influence (SI) × Experience (estimate = -0.075, $p = 0.061$) → a marginal interaction suggesting that SI may have a greater impact on BI for beginners;
- Other interactions (PE, EE, FC, HM, PV, PI × Experience) were not significant, indicating that these predictors function similarly across all experience levels.

To conclude, HT is the most influential predictor of BI, and its effect is stronger for beginners. Similarly, SI's impact decreases with experience, indicating that social influence matters more for beginners to some extent. PE and HM remain strong predictors regardless of experience level. Experience does not moderate EE, FC, PV, or PI, indicating that these factors do not change significantly based on user expertise.

To further explore the role of experience, a one-way ANOVA was conducted to examine whether mean scores for UTAUT2 predictors (PE, EE, SI, FC, HM, PV, HT, PI) differ across the three experience groups (Beginners, Intermediate Users,

Experienced Users). The results indicate significant differences across all predictors (Table 2, Appendix). These findings confirm that experience significantly shapes how users perceive key AI adoption factors, reinforcing its role as a critical segmentation variable in AI adoption research.

5 Discussion

The findings of this study provide important insights into the role of experience as a moderating factor in the adoption of ChatGPT among Generation Z. The results indicate that the direct effects of the UTAUT2 predictors on BI are robust, with HT, PE, HM, SI, and PI showing significant positive relationships. In particular, Habit emerged as the strongest predictor. However, the moderation analysis shows that the effect of Habit on BI is not uniform across all experience levels. The significant interaction between HT and experience (interaction estimate = –0.077, p = 0.034) suggests that the positive influence of Habit on BI is strongest among beginners and diminishes as users gain more experience with ChatGPT. This finding implies that while initial usage may be driven strongly by habitual behaviour, over time, the additional impact of habit declines as users become more proficient. Other factors likely influence their overall behavioural intention. Similar patterns have been observed in prior research, where the strength of habit as a predictor of continued technology use tends to diminish as users develop more refined usage patterns and internalize the technology (Venkatesh & Bala, 2008; Strzelecki, 2023).

The interaction between Social Influence and experience (interaction estimate = –0.075, p = 0.061) is marginally significant, trending in the expected direction. This indicates that SI may have a relatively stronger impact on BI for beginners compared to more experienced users. This aligns with earlier studies highlighting that early adopters often rely on peer recommendations and societal cues during the initial stages of technology adoption (Cabrera-Sánchez et al., 2021; Alalwan et al., 2017). In contrast, as users become more experienced, they appear to rely less on social validation when forming their usage intentions.

In contrast to HT and SI, the interaction effects for the other UTAUT2 predictors (PE, EE, FC, HM, PV, and PI) were not significant. This suggests that factors such as Performance Expectancy and Hedonic Motivation exert a relatively stable influence on BI regardless of a user's experience level. Thus, while these predictors

are critical drivers of technology adoption, their effect does not appear to be affected by prior experience with the technology.

Beyond its moderating effect, experience also influences how users perceive key adoption factors, as evidenced by significant ANOVA results across all UTAUT2 predictors. More experienced users exhibit stronger habit formation, higher performance expectancy, and greater enjoyment of ChatGPT compared to beginners. On the other hand, beginners rely more on social influence and perceive ChatGPT as more effort-intensive to use. Facilitating conditions and price value also differ across experience groups, suggesting that resource availability and cost-benefit perceptions shift as users become more accustomed to AI tools. These findings suggest that experience is a critical segmentation variable in AI adoption research, reinforcing the need for tailored strategies that address the unique needs of beginners, intermediate users, and experienced adopters.

The results of this study provide insights for businesses, educators, and AI developers seeking to enhance AI adoption strategies. Since habit is crucial for inexperienced users, AI applications like ChatGPT should encourage engagement through gamification, personalization, and habit-forming design strategies (e.g., reminders, content recommendations). Since social influence is critical for beginners, AI adoption campaigns should leverage peer testimonials, influencer endorsements, and community engagement to attract first-time users. Understanding that experience reduces the reliance on social influence suggests that AI literacy programs should focus on building early familiarity with AI tools, enabling users to make independent adoption decisions.

While this study offers valuable insights, several important limitations should be noted. The sample consists exclusively of Generation Z users in Croatia, limiting generalizability to other populations. Future studies should examine whether these moderation effects hold across different generations and cultural contexts. In addition, the study relies on self-reported survey data, which may introduce response biases. Future research could integrate behavioural tracking data to validate self-reported AI usage patterns. This study focused on experience as a moderator, but future work could explore other potential moderators, such as education level or personality traits.

6 Conclusions

This study examined the role of experience in AI adoption, focusing on its moderating effect on key predictors of ChatGPT usage intention among Generation Z. By applying the extended UTAUT2 model, the research confirmed that habit (HT), performance expectancy (PE), hedonic motivation (HM), social influence (SI), and personal innovativeness (PI) are the most significant factors influencing behavioural intention (BI) to use ChatGPT. However, the study also demonstrated that experience is a crucial variable that both moderates adoption behaviours and differentiates user perceptions of AI adoption factors. The moderation analysis demonstrated that while Habit (HT) is a key driver of BI, its relative influence is more pronounced among less experienced users. Conversely, social influence (SI) is more important for beginners, indicating that first-time users rely on peer recommendations and societal norms when adopting AI. Additionally, ANOVA results showed significant differences across experience levels for all UTAUT2 predictors, further reinforcing the notion that individual predictors and prior user exposure shape AI adoption. As AI tools continue to evolve, understanding how different user segments interact with them is critical. This study underscores the importance of experience in shaping AI adoption behaviours, paving the way for more targeted and effective AI adoption strategies in business, education, and technology development.

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Appendix

Descriptive Statistics and Reliability Measures

Construct	Mean	SD	Cronbach's Alpha
Performance Expectancy (PE)	5.25	1.22	0.84
Effort Expectancy (EE)	5.99	1.02	0.89
Social Influence (SI)	3.98	1.57	0.92
Facilitating Conditions (FC)	5.72	1.02	0.75
Hedonic Motivation (HM)	5.73	1.15	0.89
Price Value (PV)	4.91	1.27	0.88
Habit (HT)	2.84	1.63	0.89
Personal Innovativeness (PI)	4.36	1.59	0.86
Behavioural Intention (BI)	4.35	1.57	0.85

Source: Authors' research

Descriptive Statistics and Reliability Measures

Construct	ANOVA	Key Finding
Habit (HT)	$F = 90.02$, $p < 0.001$	Experienced users exhibit significantly higher habitual use compared to beginners.
Social Influence (SI)	$F = 42.41$, $p < 0.001$	Beginners rely more on social influence than experienced users.
Performance Expectancy (PE)	$F = 68.12$, $p < 0.001$	Experienced users perceive ChatGPT as more useful than beginners.
Hedonic Motivation (HM)	$F = 25.46$, $p < 0.001$	Experienced users derive more enjoyment from ChatGPT than beginners.
Effort Expectancy (EE)	$F = 22.22$, $p < 0.001$	Beginners find ChatGPT more difficult to use than experienced users.
Facilitating Conditions (FC)	$F = 18.54$, $p < 0.001$	Experienced users perceive better access to necessary resources.
Price Value (PV)	$F = 29.59$, $p < 0.001$	Perceived cost-benefit of ChatGPT varies across experience levels.
Personal Innovativeness (PI)	$F = 51.31$, $p < 0.001$	Experienced users are more willing to experiment with AI tools.

Source: Authors' research

Socially Responsible Employment: Expectations of New Entrants in Hungary

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Ensuring high-quality labour is crucial for companies, and socially responsible employment practices play a key role in attracting and retaining talent. This study examines the preferences of new labour market entrants regarding corporate social responsibility in employment. As organizations increasingly integrate CSR strategies, understanding how these initiatives align with the values of young professionals is essential for workforce sustainability and organizational success. The research was conducted in late 2024 and early 2025 through an online survey targeting Hungarian university students studying economics and business. The study explored students' perspectives on various socially responsible employment practices, such as benefits, hybrid work options, career development opportunities, and workplace atmosphere. Findings indicate that students prioritize a supportive work environment and meaningful internal communication. A strong positive correlation was observed between key employment practices, confirming their interdependence. Gender differences emerged, with women valuing benefits more than men. Entrepreneurial experience influenced perceptions, as those without business experience rated socially responsible employment practices as more important. These insights can help companies tailor CSR policies to better meet the expectations of young professionals, ensuring both employee satisfaction and long-term business success.

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1 Introduction

It is crucial for companies to sustain high quality labour. One of the most important contibuting factors are providing socially responsible employment. This study explores the preferences of new entrants to the labor market regarding socially responsible employment practices. As organizations increasingly adopt corporate social responsibility (CSR) strategies, understanding how these practices resonate with younger workers is crucial. By examining the attitudes of recent graduates and job seekers, this research sheds light on the growing importance of sustainability, ethical behavior, and inclusive practices in shaping employment decisions. The findings contribute to the broader conversation on how companies can align their policies with the values of the next generation of professionals, ensuring both organizational success and societal well-being.

2 Literature review

Socially responsible employment can be defined by company practices and initiatives that have a positive impact on the physical working environment and the psychological well-being of employees (Turker, 2009). The World Business Council for Sustainable Development defines employer responsibility as "[...] the commitment of business to contribute to sustainable economic development, working with employees, their families, the local community and society at large to improve their quality of life." (WBCSD, 2002). Since the 2010s the concept of sustainability has increasingly taken over the role of responsibility, and the term 'sustainable work' was coined. This concept is used to describe the life and working conditions that support workers active employment and engagement over the life course (Eurofound, 2015).

Attracting the right number of suitable future employees and preventing employees from leaving their jobs in a given period is becoming more and more challenging for companies (Nijs et al., 2014) partly because of changing employee expectations and workforce dynamics (Sparrow & Makram, 2015). University students, the new entrants in the labour market some of whom are already employed or soon will be searching for work are exceptionally important for employers in leading sectors, especially IT & telecom and the services sector in general.

According to an HR survey in Hungary (Randstad, 2024) 34% of companies were planning to increase the headcount in 2024. Some fast-growing sectors, such as power and utilities, IT & telecom, BSS and the services sectors were especially keen to attract new employees. High turnover is also often leading to employee replacement. The most sought-after skills are IT/technology, engineering and accounting/finance. The most frequent (88% of companies reported on this) obstacle when recruiting is unrealistic salary expectations, but work-life balance expectations are still relatively high (33%). Other HR challenges include retaining top performers and employee development (72% of companies reported on this), managing high turnover, ensuring employees' mental health and aligning flexible working-hours with the business needs.

Several employment surveys (Brandfizz, 2023; PwC, 2024) found that attractive salary and benefit packages remain the top need when choosing a workplace and the number one reason to switch workplaces. Among the Gen Z age range (between 18 – 24 years of age) 29% intended to switch and 19% switched workplaces in 2023 (Randstad, 2023). Besides base salary, work-life balance, supportive teams and leaders, opportunities to learn and career development and meaningful, value-creating work are the most important expectations for new entrants (PwC, 2024).

As the above survey results show both the demand, and the supply side of the labour market have certain expectations, and it is crucial to make sure that they intersect. In order to ensure intersection, companies need to measure their own socially responsible employment practices. One of the most widely used tool is the labour related disclosures of the GRI standard (Global Reporting Initiative [GRI], 2016). The disclosures cover the most vital issues of employment such as labour/management relations (402), occupational health and safety (403), training and education (404), diversity and equal opportunities (405) and non-discrimination (406). Indicators included in the disclosures specify the elements of socially responsible employment practices. The most important indicators are company communication, especially regarding major organizational changes; promoting occupational health and safety and providing such services; the organization's investment in training and paid educational leave; ratio of basic salary and remuneration of women and men.

3 Methodology

The research took place in late 2024 and early 2025, during which an entrepreneurial questionnaire was used to find out about the entrepreneurial propensity of Hungarian students studying economics and business at higher education level. The students were able to access the questionnaire via the internet, and the questionnaires had been compiled in line with GDPR regulations and the university's ethical standards, so the answers could not be traced back to the respondents. Prior to the study, a pilot survey had been conducted to see if students had a clear understanding of the questions. The (35) students participating in the pilot study did not indicate that they had any questions about the content of the questionnaire, so the questions were sent out unchanged. The questionnaire included mainly close-ended questions, typically composed of metric and categorical variables. As a metric scale, the 7-point Likert scale was used. Since this is a proprietary questionnaire, the authors will also report the results of the adequacy testing of the questions in the studies presented. The compilation of the questionnaire is shown below.

Table 1: The structure of the questionnaire

Group I Sample specification	Group II Entrepreneurial behaviour	Group III Participation in entrepreneurial training	Group IV Entrepreneurial characteristics
Gender Age Level of education of the respondents Do they have their own business?	Characteristics of own business In case of not owning a business, factors determining entrepreneurial intention	Out of class activities Curricular participation Entrepreneurial inspiration	Entrepreneurial mindset Entrepreneurial intention Socially responsible employment

Source: authors' own table

The questionnaire was distributed online, so it was not possible to measure willingness to respond. 516 students have participated in the survey. At the time of the survey, there were around 18 000 students studying at the university. To calculate the minimum sample size, the researchers used the Yamane formula (Yamane, 1967), which at the 95% confidence level was:

1. Formula (p=0.05)

$$N= \frac{N}{1 +N *(e^2)}$$

Source: Yamane (1967)

N=18 000 students, 18 000/ (1+18 000*0.05*0.05) =400. The total number of respondents was higher, so the sample size can be considered adequate. The analysis has been carried out by using SPSS version 29. Single and multiple sample tests were used: frequency, mean, analysis of variance, cross-tabulation, correlation, independent sample t-test.

In this short analysis, the researchers present the students' views on socially responsible employment. The following research questions were formulated in relation to the current study:

RQ1: What employment practices do students consider important in relation to socially responsible employment?
RQ2: What is the relationship between these practices? Do they reinforce or weaken each other?
RQ3: Is the perception of employment practices affected by gender, age and whether someone has or has had a business?

4 Results

First, sample specifications are presented. Table 2 shows sample specifications:

Table 2: Sample specification (N,%)

Specifications	N (person)	%
Gender	Male: 208 Female: 308	Male: 40.3 Female: 59.7
Level of education	HEVT[1]: 166 BA: 309 MA: 41	HEVT: 32.2 BA: 59.9 MA: 7.9
Do/Did the respondents have their own business?	No: 438 Yes: 78	No: 84.9 Yes: 15.1

Source: authors' own table

[1] HEVT – Higher Education Vocational Training

The average age of respondents was 21.42 years, with a standard deviation of 1.74 years. The data in the table show that women are over-represented in the study. More than half of those surveyed had not yet completed basic training and more than 5 times as many had no entrepreneurial experience at the time of the survey. Cross tabulation analyses showed that women and men differed significantly in whether they had ever worked in their own business (Chi-square: 13.304 df: 1 sign.: 0.000 $p<0.05$). 77.9% of men and 89.6% of women had no such experience. However, there was no significant difference in the dimensions of level of education and own business (Chi-square: 5.792 df: 2 sign.: 0.055 $p>0.05$).

In the survey, students had to answer questions such as which socially responsible employment practices they consider important for socially responsible employment. They had to rate the importance of the concept on a seven-point Likert scale. The value of one being 'not at all important', and a value of seven being 'very important'. As it was mentioned earlier, the questionnaire was not validated, so the reliability of these questions was checked using a split half method. The Spearman-Brown coefficient was 0.917, which was accepted as adequate by the authors. Table 3 shows the mean and standard deviation of student opinions:

Table 3: Socially responsible employment practices (N, M, SD)

Socially responsible employment practices	N	M	SD
Benefits	516	5.47	1.741
Hybrid work (such as flexible work)	516	5.61	1.573
Secure and pleasant physical work environment	516	5.78	1.540
Pleasant work atmosphere	516	5.82	1.590
Individual development and career plans	516	5.42	1.526
Health development plans	516	5.14	1.710
Meaningful and effective internal communication	516	5.85	1.564

Source: authors' own table

The low value of the standard deviations shows that the students surveyed were unanimous in their opinions about the socially responsible practices. Students rated a pleasant work atmosphere (M: 5.82) and meaningful and effective internal communication (M: 5.85) most important while health programs were the least important (M: 5.14). Benefits were rated as very important by 248, hybrid work by 248, a safe environment by 308, a pleasant working atmosphere by 328, individual training and career plans by 203, health programmes by 175 and meaningful communication by 336.

The impact of these practices on each other has also been analysed. The correlation analysis showed that these practices have a very strong positive correlation. A very strong positive correlation was found, for example, between benefits and hybrid work (r: 0.789), communication (r: 0.736), or pleasant work atmosphere (r: 0.799). Similarly strong relationships were found between individual training and hybrid work (r: 0.738), a secure physical work environment (r: 0.769), or communication (r: 0.779). It has been confirmed that all socially responsible employment practices listed in Table 3 induced a positive correlation with each other in the study.

It has also been analysed whether the perception of these practices is influenced by respondents' gender, age and entrepreneurial experience.

By gender, the independent samples t-test for benefits only confirmed a significant difference (t: -2.709 df: 404.129 $p<0.05$), with women feeling more strongly (M: 5.64) than men (M: 5.21) about the importance of this.

The correlation test by age was only significant for communication, but even in this case the r value showed only a very low positive correlation (r: 0.099 sign.? 0.025 $p<0.05$).

Finally, students' opinions differed for each practice in terms of entrepreneurial experience, meaning that those who had not yet had a business considered the options listed more important than those who already had one. Admittedly, these results can only be treated with caution, as those with no entrepreneurial experience were significantly over-represented in the sample.

5 Discussion and conclusions

This study explored the preferences of university students entering the labour market regarding socially responsible employment practices. The findings indicate that students prioritize a supportive and pleasant work atmosphere as well as meaningful internal communication, suggesting that these factors play a crucial role in their workplace expectations. A strong positive correlation was observed among key employment practices, confirming their interdependence. Additionally, gender differences were found, with women valuing benefits more than men. Entrepreneurial experience also influenced perceptions, as students without

business experience rated socially responsible employment practices as more important.

The results align with previous research that highlights the growing importance of socially responsible employment in attracting and retaining talent (Turker, 2009). The literature emphasizes the need for companies to offer sustainable working conditions to support long-term employee engagement (Eurofound, 2015), which is consistent with our findings that students place high importance on a positive work environment and career development opportunities. Additionally, prior studies (Randstad, 2024; PwC, 2024) underline that attractive salary and benefits remain top priorities for young workers, reinforcing our observation that benefits were particularly important to female respondents. However, while the literature often highlights work-life balance as a crucial factor (Sparrow & Makram, 2015), our study found that students were more focused on internal communication and workplace atmosphere. This deviation may be attributed to generational shifts in workplace expectations or the specific cultural context of Hungarian university students.

Based on the findings, our broad practical recommendations for companies to tailor their CSR policies to align with the expectations of young professionals by prioritizing workplace atmosphere and effective internal communication strategies to foster engagement and job satisfaction. Offering flexible work arrangements and career development programs to enhance employee retention.

While the study provides valuable insights, certain limitations must be acknowledged. First, the sample was limited to Hungarian university students studying economics and business, which may limit the generalizability of the findings to other disciplines or countries. Second, the survey relied on self-reported data, which may introduce bias or social desirability effects. Future studies could expand on this research by conducting comparative analyses across different countries and academic disciplines to determine whether similar preferences exist in other cultural and professional contexts.

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Cost-Benefit Analysis in Sustainable Tourism: Best Practices and Policy Implications

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Sustainable tourism is critical in driving economic growth, preserving the environment, and enhancing social well-being by minimizing negative impacts and maximizing long-term benefits. Cost-benefit analysis (CBA) is a vital tool for stakeholders and decision-makers to examine the feasibility and impacts of tourism projects by quantifying economic, environmental, and social factors. This study presents state-of-the-art practices in applying CBA to sustainable tourism and its use in assessing return on investment, employment, poverty reduction, biodiversity, and cultural heritage conservation. While CBA enhances decision-making, challenges remain in assessing non-market benefits and trade-offs between stakeholders. This paper synthesizes real-world applications and methodological advances and examines how CBA informs evidence-based sustainable tourism policy. Using Peja, Kosovo, as a case study, the paper identifies the need to integrate local economic, environmental, and cultural factors into QA frameworks to inform sustainable development.

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1 Introduction

Sustainable tourism development has resulted from rapid growth in the tourism industry. As described by the United Nations Brundtland Commission, (1987:16), sustainability involves addressing present needs "in a way that safeguards the ability of future generations to meet their own". The United Nations World Tourism Organization, in collaboration with UNEP (2005), emphasizes sustainable tourism as an approach that fully considers its economic, social, and environmental effects, both now and in the future, while aiming to meet the needs of tourists, the tourism sector, local communities, and the natural environment (United Nation Tourism & UNEP, 2005).

Cost-benefit analysis is critical tool in assessing the economic feasibility of tourism investments and their alignment with broader sustainable development objectives, including environmental conservation, social inclusion, and long-term community well-being (Banerjee et al., 2017). The CBA facilitates informed decision-making by identifying the costs and benefits of investments in the tourism sector while contributing to achieving the SDGs (Banerjee et al., 2017; Boardman et al., 2018; United Nations, 2015).

This paper aims to evaluate the economic feasibility of investing in sustainable tourism in Peja, Kosovo, through cost-benefit analysis (CBA). The development of sustainable tourism seeks to balance economic, social, and environmental objectives in a way that addresses the interests of both current and future generations. To this end, the paper discusses how tourism investment can contribute to economic development in the area while minimizing environmental degradation and local community empowerment. Methodology for the present research consists of the case study on the tourist sector of Peja with determining its advantages and expenses through Net Present Value analysis. The evidence proves that the development of tourism is economically worthwhile, emphasizing the fiscal importance thereof along with demands towards including the implementation of sustainability for tourist growth.

2 Theoretical Background

Cost-Benefit Analysis of Sustainable Tourism Investment

In the early 2000s, the growth of mass tourism presented obvious challenges of environmental degradation and cultural erosion for popular tourist destinations. This further increased the need for proper planning and the creation of sustainable policies. In the 2010s, studies and reports by scientists and environmental activists highlighted that while tourism can bring economic benefits, it often has harmful consequences for the environment, including increased waste and air and water pollution (Kumar, 2016; Shield, 2019; Simões et al., 2012; Unnisa & Bhupatthi Rav, 2012). With the 2030 Agenda for Sustainable Development (United Nations, 2015) tourism has become even more important for contributing to sustainable development. This highlights the responsibility of tourism to balance economic benefits with environmental protection and social well-being, as is the focus of the SDGs: economic growth, sustainable consumption and production, and ocean conservation (Elgin & Elveren, 2024; Saarinen, 2020).

Today, during the 2020s and after decade, sustainable tourism is an international priority. Governments and commercial organizations are instituting plans to minimize the undesirable impacts of tourism, such as pollution and erosion of biodiversity, along with promoting activities that maintain long-term gains. Before the onset of the COVID-19 crisis, the travel and tourism sector accounted for 10.4% of world GDP and financed 10% of world jobs (World Economic Forum, 2025). Business travel alone generated over $1.4 trillion in world GDP, indicating the industry's enormous economic contribution. World demand for international travel is projected to ***grow 7% annually from 2024 to 2034***, implying robust recovery and future growth. However, environmental degradation and resource overuse remain the key concerns in heavily visited destinations. Thus, sustainable natural resource management and authentic local community involvement are needed to foster more environmentally balanced and responsible tourism (World Economic Forum, 2025).

Hefner et al. (2001) stated that applying CBA helps government authorities assess the value and potential impact of investments in tourism development. This can ensure that public money is used effectively and in line with the SDGs. The authors' examination of the South Carolina model proves that such evaluations are not only

plausible but also critical to formulating economically productive, socially and environmentally responsible, rational, transparent, and sustainable tourism policies. Based on two hypothetical projects, study shows that the benefits of public investment in tourism sector exceed the costs. This makes it worthwhile to offer different forms of support, such as lowering taxes to stimulate growth in this industry. It can be deduced from this reasoning that there are positive effects to be gained, as well as significant investment opportunities, by building infrastructure and advertising tourism, which would help to advance the economy and development of the country through job creation, higher wages, and improved living standards for the people in the region.

Rezapouraghdam et al. (2018) employ cost-benefit analysis (CBA) to examine the socio-economic impacts of educational tourism in Famagusta from the perspective of local business people. The research identifies a number of benefits, including economic growth, job opportunities, and the establishment of new businesses, primarily induced by the presence of Eastern Mediterranean University (EMU) and its international students. The real estate, banking, and insurance industries have also experienced growth due to the influx of students. The research identifies economic costs, including rising real estate prices, over-dependence on international students, and increased competition among local businesses. The labor market was affected by the employment of foreign students at lower wages, raising concerns about local worker displacement. The authors emphasize the need for balanced policies that consider both the benefits and challenges of educational tourism for sustainable development.

Destek & Aydın (2022) in their research discussed the impact of tourism on sustainable development in the 10 most visited countries according to the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model. The authors examine the impact of drivers such as urbanization, energy intensity, and tourism on a newly suggested sustainable development index from 1995-2015.Tourism is represented in their study by two proxies: tourist arrivals and tourism receipts.

The study determines that although tourism, energy intensity, and urbanization positively affect economic growth, they negatively affect sustainable development. Specifically, the effects of these variables on the sustainable development index are

adverse and significant. The results suggest that although tourism positively contributes to economic growth, its adverse effects on other elements of sustainable development outweigh its economic contributions

However, there is still mixed evidence in the literature on the appropriate methods and techniques for assessing the economic impacts of tourism investments (Banerjee et al., 2017; Boardman et al., 2018; Dwyer et al., 2016). According to Dwyer et al. (2016) *Economic Impact Analysis* and *Cost-Benefit Analysis* may give contradictory results, as economic impacts do not always translate into net benefits. An important topic in the research to date addressing the issue of harmonization between EIA and CBA (Banerjee et al., 2017; Boardman et al., 2018; Dwyer et al., 2016; Hefner et al., 2001; Saarinen, 2020). Banerjee et al. (2017) analysed tourism investment by combining two key methods, Computable General Equilibrium (CGE) and Cost-Benefit Analysis (CBA**),** into a comprehensive framework for evaluating public investments. It examines impacts from both a development bank's and a government's perspective, including loan repayment over time. (Elgin & Elveren, 2024; Hefner et al., 2001) in their study, were using the Net Present Value method within the cost-benefit analysis, which helps harmonize EIA and CBA and provide comparable estimates for policymakers.

Vanhove (2013), highlights the importance of proper investment appraisal methods in tourism, where the public sector is usually engaged in project financing. Social Cost-Benefit Analysis (CBA) use is necessary, particularly when considering broader macroeconomic effects and externalities of tourism infrastructure projects. Contrary to traditional investment procedures focusing on private returns and costs, CBA considers all social returns and costs, e.g., environmental impacts and non-market values like consumer surplus. The research also emphasizes using accurate valuation techniques, such as the Travel Cost Method and Contingent Valuation Method, to improve the estimation of tourism project economic and social gains. Lastly, CBA offers an integrated framework for measuring the long-run and extensive consequences of tourism investments in a manner that guarantees society derives the most benefits without any unwanted externalities. This method gives valuable feedback to decision-makers, particularly about ensuring that investments are financially viable and socio-beneficial to the general population.

3 Methodology

This study employs a **case study approach** to demonstrate the procedure for evaluating tourism investments, a common topic in literature. It uses a **cost-benefit analysis**, including **Net Present Value (NPV)**, to assess the feasibility of investing in Peja's tourism sector.

The investment cost data for the tourism project were sourced directly from the Office of the Tourism Director in Peja and include expenditures for infrastructure, facilities, marketing, and administrative setup. To estimate revenue, we calculated total tourist spending by multiplying the projected number of tourists by the average number of nights each tourist stays and the average daily spending per tourist. The average daily spending was derived from Erasmus+ "cost of stay" standards, providing a standardized and realistic estimate of tourist expenditures in the region.

The **discount rate** of **3.2%** is derived from Kosovo's **T-bill rate** and the **Country Risk Premium**, reflecting the financial and economic conditions in Kosovo. Cash flows from 2021 to 2024 are discounted using this rate. NPV was calculated manually and with Excel's **NPV** functions. Table 1.

The NPV method adjusts future income and expenses to 2025 euros by applying a discount rate that includes the country risk premium. This allows for comparing income and expenses in present terms. After adjusting, expenses are subtracted from income to calculate the NPV, which helps determine if the investment is profitable. A sensitivity analysis was conducted for the Net Present Value (NPV), considering variations in the average spending per night by tourists, ranging from €80 to €100, and adjusting for a country risk premium between 3.2% and 5%.

Cost benefit Analysis Methodology: Peja Example

Peja, or the Flower of Dukagjin, is a warm and welcoming city in western Kosovo, nestled within the Rugova Mountains and Lumbardhi River. With 75% of its land covered in flora as the gateway to Bjeshket e Nemuna National Park, it is little wonder that Peja has a vibrant, youthful population. Renowned Olympic success in judo and rich artistic heritage, Peja is a cultural treasure (https://pejatourism.org/).

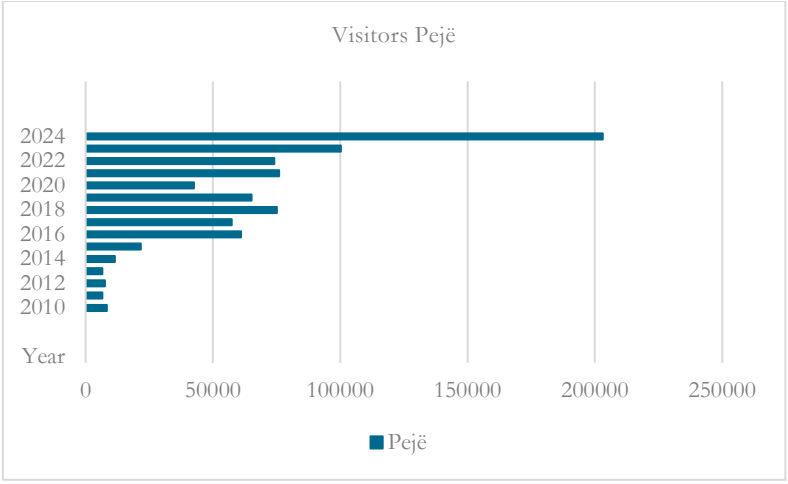

Figure 1: Trends in Tourist Arrivals in Pejë (2010–2024). Source: Author's presentation based on Kosovo Agency of Statistics data.

Figure 1. shows how the number of tourists in Pejë has grown from 2010 to 2024. The data shows an increase from 2010 until 2014, then a sharp rise in 2015, and a further rise with some fluctuations in the subsequent years. Notably, the number of tourists was highest in 2024, as 203 077 tourists visited the place. This shows strong post-pandemic recovery and potential for future growth in the tourism sector of Pejë.

Table 1: Tourism Revenue and Key Metrics in Kosovo (2021–2024)

Year	Investments cost	Number of tourists	Average Nights per Tourist	Total Nights	Average spending per tourist per day/ night according ERASMUS + per Kosovo in Euro	Country Risk Premium for Kosovo
2021	92695	76,013	2.07	157,601	92	3.23%
2022	124000	74,039	3.01	222,652	92	3.23%
2023	228794	100,204	4.60	460,984	92	3.23%
2024	310000	203,077	2.91	591,674	92	3.23%

Source: Author's calculation based on data from Tourism department in Peja. Note: Investment cost per year includes: expenditures for infrastructure, facilities, marketing, and administrative setup.

This table 1 shows key tourism metrics in Kosovo (2021–2024), with stable trends across most indicators. **Total revenue**, calculated using the **average daily tourist spending in Peja based on Erasmus+ cost of stay standards**, increased significantly each year, peaking in 2024.

Table 2: Discounted Cash Flow and Net Present Value Analysis for Tourism Investment

Year	*Investment Cost (€)*	*Total Revenue (€)*	*CR P%*	*FV Factor*	*FV Revenue (€)*	*FV Costs (€)*
2021	*92695*	*14499292*	*3.23*	*1.136*	*16,465,332.51*	*105,264.04*
2022	*124000*	*20483984*	*3.23*	*1.100*	*22,533,684.53*	*136,407.88*
2023	*228794*	*42410528*	*3.23*	*1.066*	*45,194,494.59*	*243,812.79*
2024	*310000*	*54434008*	*3.23*	*1.032*	*56,192,226.46*	*320,013.00*
				NPV of Known Investments	*140,385,738.09*	*805,497.71*

Total Value of other investments	**€**2,800,000
NPV of Unknown Investments	€2,983,801.21
Total NPV of Tourist Income	€ 140,385,738.09
Total NPV of Investments	€ 3,789,298.92
Final NPV	**€ 136,596,439.17**

Source: Author calculation based on data from Tourism department in Peja. Note: Other investments: Nera – New Environment Revitalization Approach; NATUR KOSOVO the municipalities of Peja, Dečan, and Junik; Rural Tourism – Turning our Villages into Tourism Destinations; Rural Tourism – Turning our Villages into Tourism Destinations; Accursed Mountains – Exquisite Outdoor Destination; Cultural Heritage – Treasure of the Cross-Border Region

Table 3: Sensitive Analysis

Av. Price	NPV € 136,596,439.17	Discount Rate		
Price	3%	3.5%	4%	5%
80	€ 118,285,255.94	€ 118,903,515.50	€ 120,054,961.45	€ 122,383,444.32
85	€ 125,914,915.62	€ 126,573,061.50	€ 127,798,788.21	€ 130,277,469.73
90	€ 133,544,575.30	€ 134,242,607.50	€ 135,542,614.97	€ 138,171,495.14

Av. Price	NPV € 136,596,439.17	Discount Rate		
92	€ 136,596,439.17	€ 137,310,425.90	€ 138,640,145.68	€ 141,329,105.31
95	€ 141,174,234.97	€ 141,912,153.50	€ 143,286,441.74	€ 146,065,520.55
98	€ 145,752,030.78	€ 146,513,881.10	€ 147,932,737.79	€ 150,801,935.80
100	€ 148,803,894.65	€ 149,581,699.50	€ 151,030,268.50	€ 153,959,545.96

Source: Author calculation

4 Results

The positive **NPV** results (€ 136,596,439.17) confirm the financial viability of investing in Peja's tourism sector. This **cost-benefit analysis** not only highlights strong economic returns but also underscores the potential for promoting **sustainable tourism**. By balancing economic growth with environmental and cultural preservation, the investment could contribute to both the region's development and long-term sustainability in the tourism industry. The sensitivity analysis demonstrates that higher tourist prices (from €80 to €100) enhance future value. This trend holds across varying discount rates, suggesting that prioritizing price adjustments can strengthen long-term tourism sector sustainability.

5 Conclusions

The cost-benefit analysis conducted in this study confirms that sustainable tourism investment in Peja is economically viable, with benefits outweighing costs when calculated using Net Present Value. This conforms to the argument that tourism, if managed sustainably, can be a successful catalyst for local economic development. Beyond economic dividends, sustainable tourism supports the conservation of the environment, preservation of culture, and social cohesion. Nature and heritage make Peja a flagship destination in Kosovo's tourism master plan. Its continued success, however, depends on policies reversing environmental degradation and ensuring tourism development is harmonized with host communities' well-being.

The findings welcome local and national stakeholders to strategically invest in sustainable tourism based on sound planning, stakeholder engagement, and evidence-based decision-making. Follow-up research can build on this case study by incorporating broader socio-environmental indicators and applying this model to other regions of Kosovo, guiding long-term, inclusive, and resilient tourism development.

These results are closely aligned with earlier studies highlighting the economic potential and environmental caretaking involved in tourism investment. In line with the conclusion of Hefner et al. (2001) and Rezapouraghdam et al. (2018), the current research confirms that tourism development, when properly planned and evaluated using tools like Cost-Benefit Analysis (CBA), can have net positive impacts, such as employment and infrastructure development, while also necessitating actions to manage social and environmental costs. Neither Destek and Aydın (2022) nor Dwyer et al. (2016) explain, economic growth alone cannot provide sustainability without taking into account the broader impacts on society and the environment. Further, in alignment with Banerjee et al. (2017) and Vanhove (2013), our research affirms the importance of employing integrated assessment methods considering both social welfare and financial feasibility. The results ratify the developing agreement in the literature that sustainable tourism planning must balance short-term economic gain at the expense of longer-term environmental and social issues, an imperative underscored by the Sustainable Development Goals (Elgin & Elveren, 2024; Saarinen, 2020).

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AI-Related Terminology in English as a Reflection of AI Application in Business – A Corpus-Driven Study

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A recent expansion of artificial intelligence (AI) has greatly shaped and impacted our lives, including organizations which use it in their business operations. It has also led to the emergence of AI-related terminology in English. Words such as AI-driven, AI-powered, AI-enabled, and AI-assisted used in business context indicate the complex and rapidly evolving role of AI in business. This study focuses on how these and similar phrases reflect the use of AI in business operations across a variety of industries and functional areas in business organisations. Adopting a corpus-driven approach, we analysed the frequency of selected AI-related phrases across different business sectors as presented in online media reports in English. Our findings show that AI has made its way into a vast range of business operations across different industries. Also, we highlight how these phrases, which may sometimes appear similar, reflect the functional diversity of AI applications. By analysing the scope of and the terminological distinctions between these phrases, our study adds to the clarification of the functions of AI in business and provides a precise vocabulary for discussing its many applications.

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AI-related terminology, Business English, collocations, corpus analysis, business operations

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1 Introduction

In recent years, a surge in artificial intelligence (AI) use has brought about profound changes in the way societies function. This also applies to the world of business, ranging from the entire economies to individual industry sectors and individual business organizations. Concerning the latter, the rapid expansion of AI has transformed operational processes at different levels. We may argue that there is hardly an industry sector today that has not yet been affected by or has not yet introduced the use of AI, or that AI has not yet made its way into business operations within various functional areas.

The increased use of AI in many spheres is also reflected in the English language with the emergence of AI-related adjectival phrases which indicate its various applications. Examples of such phrases are *AI-enabled 'X'*, *AI-powered 'X'*, *AI-generated 'X,'* *AI-driven 'X'*, *AI-based 'X'*, *AI-supported 'X'*. While these terms might appear similar at first glance, they nevertheless differ in the scope of AI engagement. Therefore, it is important to understand how these phrases are different from one another, i.e. what conceptual differences they express, as it points to the extent to which businesses and economies rely on AI or, in other words, the extent to which humans (still) control and manage business operations.

The aim of this contribution is to report on our analysis of the frequency of different AI-related phrases in media discourse in terms of various forms and levels of AI application in business contexts. We first give a brief foundation for the study by focusing on the use of AI in business. We also touch upon the grammatical category of 'ed-participles' in adjectival compounds functioning as premodifiers in noun phrases in English (i.e. the structures under investigation in the study). Next, we explain how the research was conducted. After that, we present and discuss our results. We conclude the paper by highlighting our key findings.

2 Theoretical framework

This section of the paper brings a brief overview of how AI is applied and used in today's business across different industries or functional areas and a short presentation of 'ed-participles' in adjectival compounds functioning as premodifiers in business-related noun phrases, which are the focus of our research.

2.1 AI use in business contexts

In recent years, AI has made its way into various industries and business operations at different degrees of integration from AI-supported processes to full integration of AI with AI-generated content. We may argue that today there is hardly any industry or business function that has not been impacted by AI, including marketing and advertising, finance and banking, supply chain management and logistics, human resources and recruitment, to name but a few. Table 1 shows examples of AI use or AI integration across these industries / business functions.

Table 1: The use / application of AI across industries or business functions

industry / business function	examples of ai use or ai integration
marketing / advertising	marketing-related decision-making, marketing-related operational efficiency, relationship marketing, marketing content creation, B2B marketing, branding, advertising design, virtual (AI) influencers, marketing automation, sales predictions, etc.
finance and banking (including insurance industry)	customer support chatbots in consumer banking, boosting financial performance of banks, financial security, capital markets, money transfers, insurance-related customer segmentation, premium calculations, claim settlements, personalized insurance products, etc.
supply chain management and logistics	inventory management, costs reduction, the minimization of the supply/demand mismatch, industry-related supply chain, country-related supply chain, etc.
human resource management and recruitment	overall recruitment practices, job postings, pre-screening processes, background investigation of candidates, ranking of the candidates, etc.

(Sources: Ali & Kallach, 2024; Ali et al., 2024; Anwar et al., 2023; Baffour Gyau et al., 2024; Bamberger et al., 2025; Bonechi et al., 2024; Corea, 2019a; Corea, 2019b; Deng et al., 2024; Ford et al., 2023; Gieselmann et al., 2025; Graham et al., 2025; Hartmann et al., 2025; Hendriksen, 2023; Jafar et al., 2023; Jorzik et al., 2024; Keegan et al., 2022; Kumar et al., 2024; Li et al., 2024; Manning et al., 2022; Mithas et al., 2022; Osadchaya et al., 2024; Praveen et al., 2019; Raab et al., 2025; Roumbanis, 2025; Roy et al., 2025; Sjödin et al., 2021; Wang et al., 2024; Yum et al., 2022).

2.2 Ed-participles in adjectival compounds functioning as premodifiers in noun phrases

Adjectives (and adjectival compounds) are words which attribute certain qualities or characteristics to nouns or noun phrases. In other words, they clearly identify them and provide descriptive details about them (Biber et al., 2021, p. 511). In this attributive function, they are positioned before the noun (or noun phrase) (e.g. *innovative* solutions, *analytical* approach). Formally, adjectival compounds take many

different forms (Biber et al., 2021, p. 530), and one of them is the form including the 'ed-participle' structure. The ed-participles are derived from verbs, e.g. *to assist* (verb) ® *assisted* ('ed-participle'), *to produce* (verb) ® *produced* ('ed-participle'), *to make* ® *made* ('ed-participle'). Semantically, they express the same meaning as the corresponding verbs (as the words which describe some kind of action), and any verb can be used in the 'ed-participle' structure. In adjectival compounds, they function as suffixes, i.e. they come after the preceding word, and they show who or what carried out the action (e.g. *self-made*, *government-assisted*, *AI-driven*, *AI-supported*).

Adjectival compounds represent a compact, integrated form of expression and they are an efficient way of compressing information into two-word construction instead of longer expressions in the form of a clause which gives the same information, which is very common in news reports (e.g. The new *AI-based system* optimizes critical business operations. / The new system, *which is based on AI*, optimizes critical business operations.) (Biber et al., 2021, p. 532).

Based on the above foundations, we formulated the following research questions:

1. Which AI-related adjectival compounds (i.e. *'AI-+ed-participle'* structures) as premodifiers in noun phrases most frequently occur in media reports on the use of AI in the broad economic and business contexts?
2. How do AI-related adjectival compounds express the level of AI involvement in its use?

3 Methodology

To answer our research questions, we adopted a corpus-driven approach. As our aim was to analyse the occurrence of the AI-related phrases in online media reports, we used the NOW corpus as the basis for the study. The NOW corpus is an extensive online corpus with over billion words of data from online newspapers and magazines in English across the world from 2010 to the present time and is growing on daily basis (*English-Corpora: NOW*, n.d.). We approached the analysis in several steps, with each consecutive step building on the previous one and bringing more in-depth results.

We first created a list of words including 'AI-' (i.e. *AI-**). This output was then refined by manually extracting the phrases with the '*AI-+ed-participle*' structure (e.g. *AI-based*, *AI-driven*, *AI-informed*, *AI-produced*, *AI-optimized*). To limit our research, we extracted 50 most frequent structures (verbs) for further analysis. The second step was the categorization of the '*AI-+ed-participle*' structures into separate groups based on the scope of AI involvement in the processes. This was done by analysing the meanings of each 'ed-participle' (functioning as the adjective describing a state resulting from the verb the 'ed-participle' derives from, e.g. '*to optimise – optimised*', '*to base – based*', '*to generate – generated*', '*to assist – assisted*'). To find different shades of meaning of each 'ed-participle' and its related verb, we consulted three online dictionaries, i.e. Cambridge English Dictionary (Cambridge University Press, 2024), Oxford English Dictionary (Oxford Universiry Press, 2024), and Collins Dictionary (Collins Dictionary, 2024). After this stage was done, we categorized the established adjectival compounds into groups based on the level of AI involvement / integration. We used Microsoft Excel spreadsheets to manage the data. The results of our analysis are given next.

4 Results and discussion

In this section we present and discuss our findings for each research question separately.

4.1 Research question 1

The first research question addressed the frequency of adjectival phrases structured '*AI-+ed-participle*' functioning as premodifiers in noun phrases. As presented in the methods section, we focused on the most frequently occurring verbs as 'ed-participles'. Figure 1 presents those which occurred more than five hundred times in the NOW corpus.

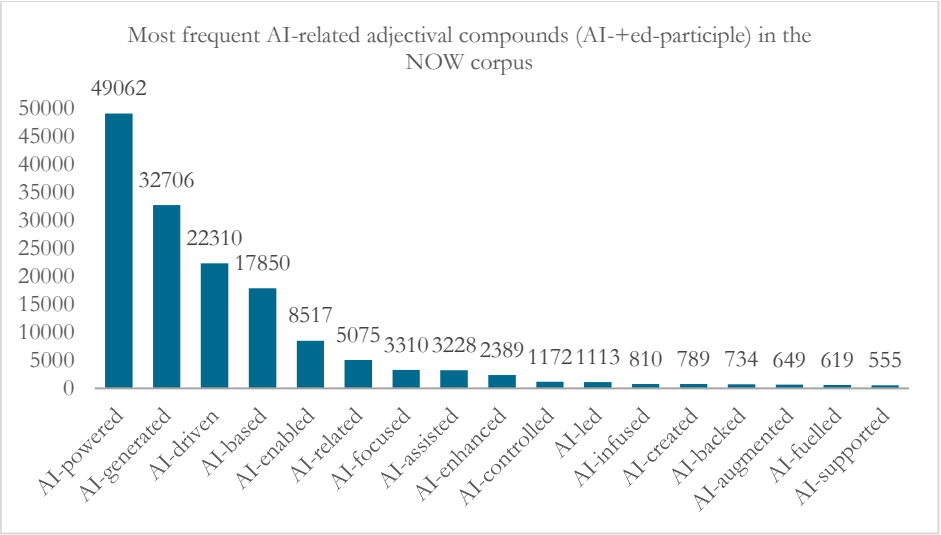

Figure 1: Most frequent AI-related adjectival compounds (AI-+ed-participle) in the NOW corpus.

The above Figure 1 shows a distinctive dominance of five verbs, which could be seen as a first potential indicator of the extent to which AI is integrated into various social, economic and business activities. That is, media reports most often address AI as being the tool which powers activities, generates various outputs, drives operations or activities or acts as their basis, makes some activities possible (i.e. it enables them), or AI helps or improves operations, tools, activities, etc.

Apart form the above most frequent verbs, the corpus included a number of those which were less frequent. Despite their lower frequency, they are nevertheless important as they show a variety of verbs that can be used to describe the applications of AI in the business context. Their frequencies are given in Figure 2 below.

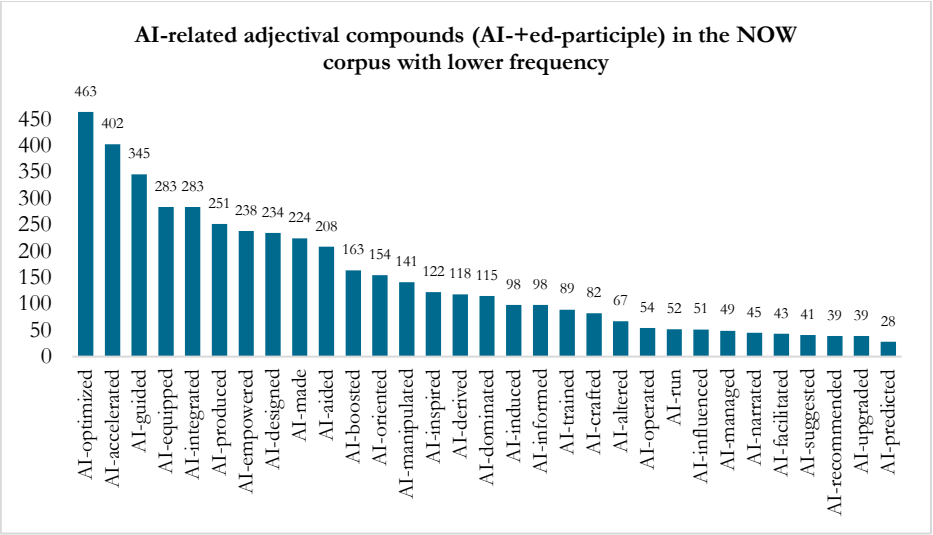

Figure 2: AI-related adjectival compounds (AI-+ed-participle) in the NOW corpus with lower frequency.

4.3 Research question 2

The second research question was closely related to the first one, and it was aimed at categorizing the established adjectival compounds as premodifiers in noun phrases regarding the level of AI involvement from (almost) full AI control or autonomy over the processes to general association of AI with operations or activities. We established that AI usage ranges from AI as the autonomous creator to being a major tool and, on the other side of the scale, to being a supplementary tool in human decision-making. Apart from that, AI is presented as a contextual, underlying framework without explicit and direct involvement in operations.

We show these four categories in the descending order of AI control from its full control to its supplementary role with the lists of adjectival phrases given in alphabetical order.

A. Full control of AI, i.e. AI as autonomous creator

The first category comprises those adjectival compounds which show AI as the primary agent, i.e. as the driving force behind the processes where there is no human intervention or human intervention is minimal. The phrases found in the corpus are

AI-controlled, *AI-crafted*, *AI-created*, *AI-designed*, *AI-dominated*, *AI-driven*, *AI-generated*, *AI-led*, *AI-made*, *AI-managed, AI-narrated*, *AI-operated*, *AI-produced*, and *AI-run*.

To illustrate:

[1] *From interactive chatbots and augmented reality effects to AI-generated content, the AI features on Snapchat have increased, especially in recent days.* (GH (25-02-05)[1]
[2] *Alinea Invest, a fintech app offering AI-powered wealth management aimed at Gen Z women, has $3.4 million in seed funding ahead of the launch of a virtual AI assistant that will help users with their investing needs.* (US (24-01-24))
[3] *Over time, as the AIs continue to improve, hybrid subscription sites might emerge, with both human- and AI-produced content.* (ZA (24-04-07))

The common denominator of these adjectival compounds is creation and control. That is, they express AI's capacity for autonomous action or influence. As such, they show AI in the position of an active agent, i.e. something that is not passive but "has the ability to take action or to choose what action to take" (Cambridge University Press, 2024). Specifically, these terms show AI as something that can create, direct, or manage complex operations.

B. Strong involvement of AI, i.e. AI as a significant contributor to human-led processes

The second category of adjectival compounds includes those which point to AI as something that works together with humans or systems in a quite substantial way. The phrases found in the NOW corpus are *AI-accelerated*, *AI-altered*, *AI-augmented*, *AI-backed*, *AI-boosted*, *AI-empowered*, *AI-enhanced*, *AI-equipped*, *AI-fuelled*, *AI-guided*, *AI-infused*, *AI-integrated, AI-manipulated*, *AI-optimized*, *AI-powered*, and *AI-upgraded.*

We illustrate their use in business context with the following examples:

[4] *AI-accelerated organisations are also looking at benefits beyond productivity – operations- and process-level improvements, such as automating key business processes or redesigning roles to work with chatbots.* (ZA (24-11-05))

[1] The references in the brackets refer to concordance lines and sources in the NOW corpus (as accessed on 10th March 2025).

[5] *But there's now also a new AI-backed tool to help business owners design their own visual asset […] as well as a tool to help them write better email subject lines.* (US (20-09-22))
[6] *These new AI-equipped products provide our consumers with a superior smart home experience and have received favorable market feedback and reviews.* (US (22-08-22))

Collectively, the phrases in this category express strong involvement of AI in (business) operations. That is, AI is seen as a significant and complementary tool, as something that substantially enhances human activities by being incorporated in these activities without replacing humans as the agents. Here, AI is not an independent agent, but it amplifies human-led processes and human abilities by, for example, improving efficiency and speed of operations, by optimizing, supporting and directing workflows, by providing support validation for human decisions, etc.

C. *Supportive role of AI, i.e. AI as a supplementary tool in human-led processes*

The third group of adjectival compounds in our analysis contains those which show AI as something that aids human activities, but not at the same extent and scope as was the case with the second category. Here, we find phrases such as *AI-assisted*, *AI-aided*, *AI-supported*, *AI-facilitated*, *AI-informed*, *AI-suggested*, *AI-recommended*, *AI-influenced*, and *AI-predicted*. The following examples from the NOW corpus show their use in context:

[7] *The 2023 holiday shopping season saw the highest average discount rate since 2020 and an increase in AI-influenced purchases, according to new research by Salesforce.* (ZA (24-01-12))
[8] *The OTAs are well prepared to make bookable any AI-suggested itinerary with their 2.5 million multi-room accommodation establishments.* (US (23-05-08))
[9] *Meta's pivot towards AI-recommended content, which has received mixed feedback, may also be contributing to more time spent on the platform.* (SG (24-10-12))

Overall, the 'ed-participles' in the above adjectival compounds point to the AI having a supporting or assisting role or function and humans maintain primary control over the processes. That is, AI is a helpful tool which only supplements human work and does not fundamentally transform it. It helps individuals perform their tasks more effectively, it makes processes easier. Also, AI provides data-driven information, insights, options, and recommendations which humans may either accept or reject. In other words, humans retain agency when it comes to processes

and operations, i.e. they are in control, and they use AI selectively to improve specific aspects of their work-related processes.

D. AI as a framework, i.e. general reference to and broad association with AI

The last group of adjectival compounds in our analysis was the group which contained those cases that point to AI's principles or technology rather than its direct involvement in human-led operations. The phrases we found in the NOW corpus are *AI-based*, *AI-derived*, *AI-focused*, *AI-induced*, *AI-inspired*, *AI-oriented*, *AI-related*, and *AI-trained*. The examples below illustrate their use in business context:

[10] *India has been ranked 2nd on the Stanford AI Vibrancy Index primarily on account of its AI-trained workforce.* (IN (22-02-16))
[11] *Findings from Bain & Company revealed that AI-related job postings have surged by 21% annually since 2019, with compensation for such roles increasing 11% in the same period.* (SG (25-03-05))
[12] *AI interfaces and chatbots have redefined customer services, and its growing popularity will enable the AI-oriented fintech market to expand at a CAGR of 21.72% during the (2021-2026) period.* (IN (21-10-23))

The common denominator of adjectival compounds in this category is conceptual association. That is, they show different connections to AI in the sense that AI is the source of or the foundation for ideas, a point of reference. Further, they do not express the active role of AI in processes. In other words, AI is perceived as the context of and not as the agent in operations.

5 Conclusions

Our paper addressed the integration and use of AI in business from a linguistic perspective. That is, based on a corpus of online news and media reports in English regarding the use of AI in business, we examined specifics of AI-related terminology. Specifically, we focused on adjectival compounds structured as '*AI-+ed-participle*'. Our key takeaways from this linguistic study are the following.

First, there are many verbs in English which are associated with the application of AI. This is the primary indicator of its growing role in business and, consequently, economies around the world. Second, the spectrum of AI-related terminology in

English as researched in our study spans from AI being presented as having full autonomy (i.e. AI operates independently and generates or controls outputs) via strong integration of AI in human work (i.e. AI significantly optimizes or enhances business processes) to AI being only a supportive tool (i.e. AI assists human work, such as operations, decision-making), a source of information and insights. Apart from these three categories, AI serves as a conceptual framework rather than being directly involved in business operations.

Connecting the business aspect and the linguistic aspect, we can argue that understanding AI integration-related linguistic nuances as presented in this contribution may help in preparing further frameworks for addressing AI implementation in business and the economy. Our results may also serve as food for thought regarding the impact of AI on business practices and its (ethical) implications. From a purely linguistic perspective, we see that AI-related terminology is evolving and may predict that new English terms connected with its use will continue to emerge. Overall, our study adds to the understanding how language reflects the multifaceted relationship between AI and business operations in various industries.

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Personal Purpose as a Key Driver of Commitment in Public Organizations: The Role of Purpose Identification

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In recent years, researchers have begun exploring the concept of purposeful business, in which employees' personal purpose plays a key role. Purposeful business significantly contributes to developing positive behaviors and outcomes, such as increased engagement, enhanced commitment, and improved individual and organizational performance. However, previous research has largely focused on observing purposeful business exclusively in private organizations. This study examines the relationship between personal purpose and commitment in public organizations, focusing on the moderating effect of purpose identification. A survey was conducted among 160 employees from seven Croatian public organizations. Moderation analysis revealed that purpose identification moderates the relationship between personal purpose and commitment. These findings underscore that employees' personal purpose is an essential psychological mechanism for increasing their commitment, but only with the support of purpose identification. This study is the first to introduce the concept of personal purpose into the Croatian organizational context, offering new insights into purposeful business. The results provide practical implications for managers, highlighting the importance of harmonizing employees' personal purpose with organizational purpose to enhance organizational commitment. However, limitations arise from collecting data from a single source in one time period and the involvement of only seven public organizations, suggesting avenues for further research.

Keywords:
personal purpose, purpose identification, organizational commitment, public organizations, moderation analysis

JEL:
D23, M12, J24, J28

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1 Introduction

Business practices are evolving, and profit as the sole organizational objective is no longer enough. As a result, the focus in the business world is shifting toward creating purposeful business. Modern organizations need to adopt a broader perspective by clearly defining their purpose and integrating it into daily operations. This approach forms the foundation of purposeful business, which extends beyond profit as the primary reason for an organization's existence and plays a key role in rebuilding trust in business and making a positive contribution to society (Hollensbe et al., 2014). Ferreira Ribeiro et al. (2024) highlight several benefits of purposeful business for organizations and their employees, including higher employee engagement, stronger organizational commitment, improved individual performance, and enhanced organizational success. For that reason, it is inevitable that purposeful business will play an increasingly important role in the upcoming period. Building a purposeful business requires individuals to discover and align their personal purpose with the organizational purpose. Therefore, this paper examines the role of personal purpose and purpose identification in fostering employee commitment. However, existing research on this emerging concept has focused exclusively on private organizations. This study is the first to explore some components of purposeful business in public organizations, extending the concept to the public sector and bridging an important gap in the literature.

Public organizations differ from private organizations in many ways. A key difference lies in their fundamental mission and purpose. While the concept of business purpose is increasingly gaining attention, previous research has largely focused on private organizations. This paper examines the role of personal purpose and purpose identification in public organizations, which differ from the private sector in their fundamental mission and purpose. As early as 1982, Gold emphasized that private organizations are far more capable of clearly, precisely, and consistently articulating their fundamental mission and purpose than public organizations (Gold, 1982). Snir & Harpaz (2002) found that "public-sector employees had a weaker economic work orientation than private-sector employees, and they also attributed greater importance to the entitlement norm and to the notion that working was a useful way for them to serve society." For public organizations that advocate values tied to public service and the greater good of society, employees must be strongly committed to these values if public organizations effectively fulfill their purpose

(Lyons et al., 2006). However, Lyons et al. (2006) found that public-sector employees were less committed to their organizations than were private-sector employees. For this reason, it is particularly important to explore whether public-sector employees' personal purpose and identification with the organization's purpose will influence greater commitment, highlighting the urgent need for further research in this area.

2 Theoretical Background

Personal purpose and purpose identification as key components of purposeful business

For organizations and individuals to discover their purpose, it is necessary to answer questions such as: "What does your organization stand for?" and "How would society be different without your organization?" (Rey & Bastons, 2019). A purposeful business is inspired by a clear role in the world that provides it with a reason for existence and, as such, is focused on the "WHY" (Zu, 2019), where this "WHY" represents the organization's purpose (Sinek, 2009). Additionally, Chinchilla et al. (2019) emphasized that "purpose refers to the identity of the organization, its DNA and *raison d'etre*, what makes it unique."

In order to understand the concept of purposeful business, it is crucial to consider the harmonization between personal and organizational purpose, as this harmonization is a prerequisite for productivity and overall business success (Kiefer & Senge, 1999). The harmonization of personal purpose within the organizational purpose represents the core of a purposeful business, where each individual must recognize their purpose, while at the same time, a shared purpose must be achieved, arising from the connection of individual purposes (Rey et al., 2019). Lleo et al. (2021) suggest that the success of shared purpose creation increases as employees become more aware of it, identify with it, and actively contribute to its development. Additionally, purpose identification is a key element in the process of building shared purpose and purposeful organizations (Lleo et al., 2019).

Previous research and hypothesis

There is a notable absence of empirical studies examining personal purpose and purpose identification, and such research has not been conducted in the context of public organizations to date. However, it is crucial to recognize the potential benefits

of overall organizational identification, which can lead to many positive outcomes for both employees and organizations. These benefits include lower turnover intentions, organizational citizenship behavior, job satisfaction, employee well-being, and enhanced job performance (Ashforth et al., 2008; Riketta, 2005). In addition, Guangrong et al. (2021) explored the impact of purpose and purposefulness on work engagement and commitment in a study of 879 employees. They found that employees with goals centered on helping others, advocating for causes, or career growth were more engaged in their work than those focused on fulfilling basic needs or achieving a comfortable lifestyle. More importantly, the study revealed that when employees felt a strong sense of purpose in their work, they were more engaged and committed (Guangrong et al., 2021). Therefore, the following hypothesis (H1) was formulated: *Purpose identification moderates the relationship between personal purpose and commitment.* Figure 1 shows the conceptual research model.

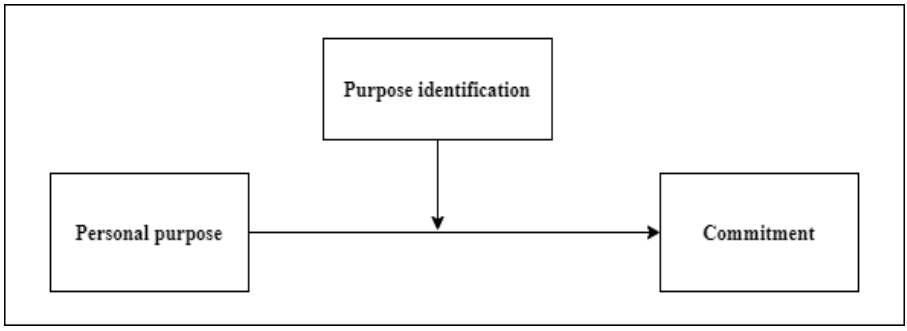

Figure 1: Conceptual research model

3 Methodology

Measures

The study aimed to test the moderating effect of purpose identification on the relationship between personal purpose and commitment, and the following well-validated measurement instruments were employed: the Meaning in Life Questionnaire (3 items, Cronbach's alpha = .97) developed by Steger et al. (2006) for assessing personal purpose; the Scale for Internalization of the Mission (3 items, Cronbach's alpha = .86) developed by Marimon et al. (2016) for assessing purpose identification; the Organizational Commitment Scale (5 items, Cronbach's alpha =

.93) developed by Allen & Meyer (1990) for assessing commitment. All measurement instruments used a 5-point Likert scale (from *1=strongly disagree* to *5 = strongly agree*).

Table 1 shows the items' descriptive statistics (total mean scores and standard deviations). As can be seen, the mean values for all items are at sufficiently high and satisfactory levels. The lowest mean value is 3.31 (SD=1.11) for the item related to measuring commitment, and the highest mean value is 4.23 (SD=.83) for the item related to measuring purpose identification. However, it can be noted that the lowest mean values were recorded for the variable *commitment*.

Table 1: Descriptive statistics of items

Item Code	Items	N	Mean	Std. Deviation
Personal purpose1	I understand my life's meaning.	160	3.98	1.00
Personal purpose2	I have discovered a satisfying life purpose.	160	3.93	.98
Personal purpose3	My life has a clear sense of purpose.	160	3.96	.97
Purpose identification1	I believe that my company's purpose/mission is important to society.	160	4.23	.83
Purpose identification2	My company's purpose/mission is aligned with my individual values.	160	3.74	.94
Purpose identification3	My company's purpose/mission is important to me.	160	4.03	.88
Commitment1	I really feel as if this organization's problems are my own.	160	3.31	1.11
Commitment2	I feel a strong sense of belongingness to my organization.	160	3.59	1.04
Commitment3	I feel emotionally attached to this organization.	160	3.46	1.12
Commitment4	I feel like "part of the family" at my organization.	160	3.35	1.12
Commitment5	This organization has a great deal of personal meaning for me.	160	3.66	1.09

Sample and procedure

In the study, a quantitative online survey questionnaire was used, and primary data were collected from October to December 2024. The data were collected from seven Croatian public organizations that employed a minimum of 20 staff members. Public organizations that participated in the study are education institutions (2), hospitals

(2), local and regional self-government units (2), and a non-profit public organization (1).

The final sample consisted of 160 respondents who participated in the survey. Regarding demographic characteristics, most respondents were between 45 years and above (45.00%) and between the ages of 30 and 44 (44.38%). Also, 118 respondents were female (73.75%), and 41 were male (25.63%). Most respondents had completed higher education - graduate, academy or postgraduate study (62.50%), and had 10 or fewer years of service in their current position (52.50%), and 10 years or fewer years of service in their current organization (48.13%). Most respondents worked as professional/administrative workers (41.25%).

Given that most respondents who participated in the research had 10 years or less of working experience in the public organization where they were currently employed, the lowest mean values for the variable *commitment* are expected. Previous research has demonstrated that the length of service in an organization is positively correlated with employee commitment (Bakotić, 2022; Meyer et al., 2002; Salami, 2008).

4 Results

Conditional process moderation analysis, as one of the regression analyses, was used to test the hypothesis using Model 1 in the PROCESS macro for SPSS (Hayes, 2018). This methodological approach allows for a robust examination of moderation effects and provides detailed insights into personal purpose effects on employee commitment. The results of this analysis are presented in Table 2.

Table 2: Results of conditional process moderation analysis

	Coeff	SE	T value	p value
Constant	3.724	*.844*	*4.411*	*.000*
Personal purpose (X)	-.621	*.248*	*-2.506*	*.013*
Purpose identification (W)	-.356	*.241*	*-1.474*	*.142*
Personal purpose x Purpose identification (XW)	**.023**	***.063***	***3.549***	***0.001***
		R^2 = .546, MSE = .664		
		F (3, 156) = 22.058, p < .05		

The results indicate a negative relationship between personal purpose and commitment (β = -.621), as well as between purpose identification and commitment (β = -.356). However, when purpose identification was introduced in the model, a positive relationship emerged between personal purpose and commitment (β = .023). These findings suggest that purpose identification moderates the relationship between personal purpose and commitment. Specifically, there is no direct relationship between personal purpose and commitment, but rather this relationship is indirect and facilitated by the moderating effect of purpose identification. More precisely, as employees' personal purpose increases, they will be more committed to their organization if they identify with its purpose. We can conclude that the positive relationship between personal purpose and commitment will increase under the purpose identification moderating variable. This proposition is shown in Figure 2. Accordingly, Hypothesis H1 can be accepted. It is important to note that the ANOVA test results show significant differences between public organizations in all three variables, indicating that employees' personal purpose, purpose identification, and commitment vary across organizations. Although the study is focused on the public sector, the results can also be discussed in the context of private organizations, especially if the specific goals and strategies companies use are considered.

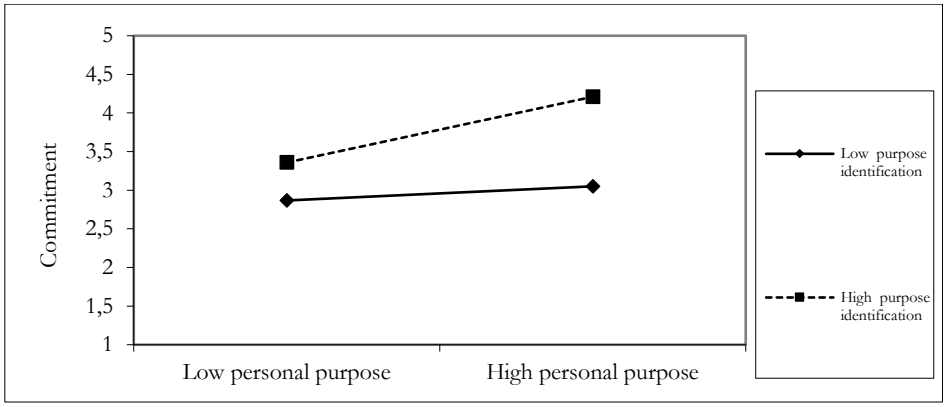

Figure 2: Moderation effect of purpose identification

5 Conclusions

This study highlights the crucial role of personal purpose in fostering commitment within public organizations, highlighting the moderating effect of purpose identification. The findings suggest that employees with a strong personal purpose are more committed to their organization when they identify with its purpose. The results contribute to the growing body of research on purposeful business by extending its scope to public organizations. This study is the first to investigate the relationship between personal purpose, purpose identification, and commitment in Croatian public organizations, providing valuable insights for both academia and practice. Public sector managers should actively work on communicating the organizational mission and its importance to society and on creating opportunities for employees to see how their individual work contributes to the realization of that mission, thereby fostering the alignment of personal and organizational purpose. However, the study has limitations, including data collection from a single source and focusing on only seven public organizations. Future research should explore these relationships in larger and more diverse samples, including longitudinal studies, to examine causal effects over time. Additionally, comparing the results with wage and benefits analysis in the public sector would provide a deeper understanding of how these factors impact organizational outcomes. Despite these limitations, the study provides a solid foundation for further investigation into the role of purpose in the commitment of public-sector employees. It offers practical recommendations for improving employee commitment and identification with the organization through purposeful leadership.

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The Role of AI in Energy Usability and Efficiency: Opportunities and Limitations

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Artificial Intelligence (AI) is increasingly shaping environmental sustainability, particularly in optimizing energy usability and enhancing energy efficiency. AI-powered solutions, such as smart grids, predictive analytics, and automated energy management systems, enable real-time monitoring and dynamic energy allocation, reducing waste and improving overall efficiency. AI-driven forecasting models also enhance renewable energy integration by predicting fluctuations in solar and wind power generation, ensuring a more stable and sustainable energy supply. Additionally, AI-enabled IoT systems contribute to energy-efficient buildings and industrial processes by autonomously regulating energy consumption based on real-time data. This study employs a mixed-method research approach, combining secondary data analysis with primary research. The primary research component consists of four in-depth interviews with experts in AI, and energy management. These interviews provided qualitative insights into the practical applications, challenges, and future potential of AI-driven energy solutions. The main findings indicate that while AI significantly contributes to energy optimization and stabilization, it also poses sustainability challenges due to its high energy consumption. Experts emphasized that AI-driven solutions must evolve towards greater energy efficiency to offset the environmental impact of AI infrastructure itself.

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1 Introduction

Artificial Intelligence (AI) can be defined as machine intelligence that is able to mimic a human mind's problem-solving and decision-making capabilities to perform various tasks (Kanade, 2025), such as preparing quality any-to-any language translations, and generating, understanding, analysing, or proofreading any text. In simplified terms, artificial intelligence operates on three primary levels. Initially, it assimilates sensory data to perceive its environment. Subsequently, it applies analytical methods to identify patterns and correlations. Finally, it refines its internal knowledge base to enable informed decision-making, thereby facilitating adaptive system optimization (LeCun et al., 2015). It is therefore no coincidence that AI has emerged as a transformative force in the energy sector, offering vast potential to enhance energy usability and improve overall efficiency (Gruetzemacher & Whittlestone, 2019). Through AI-powered solutions, such as smart grids, predictive analytics, and automated energy management systems, the energy landscape is being reshaped to enable real-time monitoring, dynamic energy allocation, and enhanced forecasting capabilities, ultimately reducing waste and optimizing resource utilization (Kumar et al., 2021).

AI exists on a spectrum of capabilities, commonly divided into three levels:

- *Narrow AI (Weak AI):* These systems are designed to perform specific tasks efficiently, such as optimizing heating and cooling in smart buildings or enhancing power distribution in smart grids. Narrow AI is already playing an important role in improving energy efficiency through machine learning algorithms that analyse consumption patterns and adjust systems in real-time. Bankins & Formosa (2023) quote Boden (2016) in their work when stating that this level of AI can be recognised as the *"holy grail"* of this technology. Also, the use of narrow AI allows us to draw on practical examples to ground our works' effectiveness.
- *General AI (Strong AI):* While still theoretical, General AI would possess cognitive abilities akin to human reasoning, thereby enabling autonomous decision-making across multiple domains. In the energy sector, such systems could implement highly adaptive, self-optimizing energy management strategies without human oversight. As Lake et al. (2017) argue, designing machines that learn and think like humans necessitates

integrating perceptual inputs, reasoning, and prior knowledge—capabilities that, if fully realized, could revolutionize dynamic resource allocation and sustainability in energy systems.

– *Super AI:* This hypothetical stage envisions an intelligence that surpasses human cognitive capabilities, with far-reaching implications for innovation. In the context of energy sustainability, a Super AI could theoretically devise novel solutions and radically transform existing paradigms. Chalmers (2016) suggests that such an intelligence might not only optimize established processes but also pioneer entirely new frameworks for energy generation and distribution, thereby addressing complex challenges that currently elude human problem-solving.

In this article, mostly the use of Narrow AI can be taken into consideration. For instance, smart grids, powered by AI algorithms, enable real-time monitoring and dynamic energy allocation, adjusting supply and demand in response to fluctuations (Fang et al., 2012). This dynamic approach maximizes efficiency by reducing energy waste and ensuring a more stable and reliable energy supply. Moreover, AI-driven predictive analytics models can enhance the integration of renewable energy sources, such as solar and wind, by accurately forecasting fluctuations in power generation, allowing for better grid balancing and storage management (Tang et al., 2022). Beyond the power grid, AI-enabled IoT systems also contribute to energy efficiency in buildings and industrial processes. These systems autonomously regulate energy consumption based on real-time data, optimizing lighting, heating, ventilation, and other energy-intensive operations (Alam et al., 2012). While AI has significantly transformed the energy sector, unlocking numerous opportunities for optimization and sustainability, it also poses significant challenges that must be addressed. It is worth to mention that AI has a highly adaptable transformative potential which can enhance energy efficiency and usability, but we have to mention that the widespread adoption of AI-powered solutions carries its sustainability implications. A key concern is the high energy consumption of AI infrastructure itself, which can potentially offset the environmental benefits it aims to achieve (Strubell et al., 2019). As AI systems become more prevalent, their energy demands are likely to increase, highlighting the need for AI-driven solutions to evolve towards greater energy efficiency. As the energy sector continues to undergo digital transformation, the role of AI in enhancing energy usability and efficiency is undeniable.

However, precisely due to these factors, a vicious cycle emerges, posing a significant challenge in finding a viable solution. While artificial intelligence (AI) systems and models are increasingly employed to enhance energy efficiency, the energy demand of AI systems themselves is escalating at an alarming rate on a global scale.

2 Literature review

The literature on the intersection of artificial intelligence, energy efficiency, and environmental sustainability reveals a multifaceted and, at times, paradoxical relationship. On one hand, numerous studies demonstrate that AI applications – ranging from predictive analytics and dynamic energy allocation to the deployment of smart grids – have been instrumental in optimizing energy management and integrating renewable sources. For instance, Phuangpornpitak et al. (2013) and Ukoba et al. (2024) illustrate how AI-driven algorithms can adjust supply and demand in real time, thereby enhancing grid stability and reducing energy wastage. These innovations enable more resilient and adaptive energy systems, which are essential for meeting the demands of modern power infrastructure. Conversely, the rapid advancement and scaling of AI technologies have raised critical concerns regarding their intrinsic energy consumption. Jiruwala (2024) argue that the energy required to train large-scale neural networks, such as those powering natural language models (referred as LLMs), can result in carbon emissions on a scale comparable to those of traditional industrial processes. This view is corroborated by Strubell et al. (2020), whose research highlights the significant environmental costs associated with deep learning, particularly in the context of computational resource demands. Furthermore, Bender et al. (2021) have sparked an important debate by emphasizing that while AI can unlock transformative efficiencies across various sectors, the computational and energy costs associated with these systems necessitate a rigorous re-examination of their long-term sustainability. In response, recent investigations by Moon et al. (2019) have focused on reducing the energy footprint of deep learning architectures through algorithmic optimizations and the integration of energy-efficient hardware. Such approaches are critical in bridging the gap between the immediate benefits of AI applications and their broader environmental impact. Practical applications of AI in energy management further underscore both the promise and the challenges inherent in this technological paradigm. Zhao (2022) demonstrates that AI-driven optimization in industrial production can lead to notable reductions in energy consumption, while Ali et al. (2024) provide evidence

that intelligent building systems – through continuous monitoring and automated control – can significantly lower operational carbon footprints. In the transportation domain, Ponnusamy et al. (2024) and Cavus et al. (2025) have documented how AI-based traffic management and predictive maintenance systems can contribute to more efficient energy use, thereby mitigating congestion and reducing emissions. Despite these promising developments, Chen (2023) cautions that the overall benefits of AI in promoting energy efficiency must be carefully balanced against its own escalating energy demands. The dual challenge lies in harnessing AI's potential to drive sustainability while simultaneously developing methods to curtail the energy intensity of AI systems themselves. As such, the literature points to a critical need for interdisciplinary research that not only expands the application of AI in energy systems but also prioritizes the creation of lower-energy-consuming models and infrastructures.

It can be stated that even if AI offers transformative potential for enhancing energy efficiency and advancing environmental sustainability, its application is marked by an inherent paradox: the very systems designed to reduce energy consumption can themselves be energy intensive. A holistic balance must be reached which can ensure that the pursuit of technological efficiency does not inadvertently exacerbate global energy challenges.

3 Methodology

This study employs a mixed-method research approach, integrating secondary data analysis with primary qualitative research. The primary research component is based on semi-structured in-depth interviews conducted with four experts in artificial intelligence and energy management. These interviews were designed to elicit comprehensive insights into the practical applications, challenges, and future potential of AI-driven energy solutions, with particular attention to sustainability issues arising from the high energy consumption associated with AI infrastructure. The semi-structured interview format was chosen to balance the need for consistency across interviews with the flexibility to explore emerging topics in greater depth. In the interview guide we formulated 20 questions to address three central thematic areas: the general understanding and conceptualization of artificial intelligence, the specific applications and operational modalities of AI within the interviewees' organizations – especially as they pertain to energy efficiency –, and

the strategies employed by these organizations to integrate AI in optimizing energy consumption. This structure allowed us to evaluate both the depth of the experts' knowledge on AI and the extent to which their organizations have implemented AI-driven solutions in the energy domain.

The central research question guiding this study was the following:

Q1: To what extent can AI-driven solutions optimize energy management while mitigating the sustainability challenges posed by the companies represented by the research participants' energy consumption?

Participants were selected through purposive sampling, ensuring that each interviewee had demonstrable expertise in either AI technology, energy management, or both. This strategic selection was necessary to collect relevant data. All interviews were recorded and transcribed verbatim to ensure the accuracy and reliability of the data. The resulting transcripts were subjected to thematic analysis, a qualitative method that involved coding the data and identifying recurring themes and patterns. Ethical considerations were rigorously observed throughout the research process. Participants were fully informed about the study's objectives, and their informed consent was obtained prior to the interviews. Confidentiality was strictly maintained by anonymizing personal identifiers and ensuring that any potentially sensitive organizational information was handled with care.

4 Results

The primary qualitative investigation involved four in-depth interviews with experts representing international companies operating in Hungary. Two of these companies belong to the telecommunications sector, while the remaining two are IT enterprises, each employing over 250 individuals. The interviews were designed to capture the current utilization of AI-driven solutions in energy management as well as the associated sustainability challenges.

A key finding from the study is that three of the four interviewees reported regular use of AI tools – engaging with these technologies for at least four hours per day and employing a minimum of three different large language models (LLMs). In contrast, one participant described a more variable usage pattern, noting, *"There are*

times when I don't need to use it even once a week, but there are times when I need to use it for 8 hours a day". This divergence in usage frequency underscores the heterogeneous integration of AI within similar organizational contexts.

When exploring the practical impact of AI on energy management, responses varied considerably among the participants. One interviewee expressed reservations regarding AI's long-term viability in optimizing energy consumption, stating, *"To my knowledge, AI systems consume a great deal of energy, so I do not believe that this would be a long-term solution for improving energy management. (...) I am not aware of this aspect being prioritized in our company's primary strategy".* This perspective highlights concerns regarding the sustainability of AI systems, particularly in terms of their energy demands.

Conversely, another expert emphasized the innovative potential of AI to uncover novel methods for reducing energy consumption. This respondent noted, *"AI's detection capabilities are remarkably precise in uncovering new innovative methods that could achieve real and more effective energy reductions, even at our company. However, at present, this is a secondary consideration because most employees are not yet at that stage".*

A third interviewee provided evidence of proactive sustainability measures within their organization, stating, *"In our company, we already have solar panels that are specifically intended to sustainably meet the energy demands of the AI systems we use (...) currently only partially, but it is already operational".* This response indicates that some companies are beginning to integrate renewable energy solutions specifically to offset the energy demands of AI systems.

Finally, the fourth participant drew attention to the rapid escalation of energy consumption associated with large language models, particularly in light of recent technological advancements such as ChatGPT. This interviewee remarked, *"By the end of 2022, when ChatGPT was introduced, we already knew that this technology would have an enormous energy demand. Just consider that every LLM system doubles its capacity every three months, which consequently increases energy consumption. However, our engineers have prepared for this in time, so we use a hardware park that consumes significantly less energy, and we strive to power it entirely with sustainable energy sources".* This insight underscores the urgency of addressing AI's energy requirements through innovative, energy-efficient technological and infrastructural solutions.

These thoughts indicate that even among large multinational companies, there is significant variability in how energy efficiency is prioritized within the context of AI deployment. While some organizations are actively pursuing sustainable practices to mitigate the environmental impact of their AI systems, others appear less committed to this aspect.

5 Discussion

Several corporate examples illustrate how AI-driven solutions can optimize energy management while addressing sustainability challenges. For instance, Vodafone, a leader in telecommunications, has implemented advanced AI algorithms for network optimization and predictive maintenance, and invested in a dedicated solar park to power its data centres, thereby reducing reliance on non-renewable energy sources (Lawrence & Durana, 2021).

In the IT sector, IBM and Intel leverages AI for intelligent building management. The facilities of these companies utilize AI-driven systems to monitor and regulate energy consumption in real time – adjusting heating, ventilation, and lighting – while integrating solar panels to ensure sustainable energy sourcing (Mahzar et al., 2022).

Additionally, leading logistics companies such as DHL and Alibaba, employ AI-based traffic management systems to optimize route planning and reduce fuel consumption. DHL is also piloting solar-powered charging stations for its electric vehicle fleet, underscoring its commitment to merging AI innovations with renewable energy solutions (Ozturk, 2024).

These examples highlight the potential of AI to enhance energy efficiency across various industries while mitigating environmental impacts. However, they also emphasize the need to balance technological advancement with sustainable practices, ensuring that the energy demands of AI systems do not offset their environmental benefits.

6 Conclusion

This study successfully achieved its objective by elucidating the dual role of AI-driven solutions in optimizing energy management and highlighting the sustainability challenges posed by their energy consumption. The integration of AI

in energy systems – evident in corporate practices at Vodafone, IBM, and DHL – demonstrates that while AI can significantly enhance energy efficiency and resource allocation, its deployment is not without environmental costs. The mixed-method research approach, particularly the use of semi-structured in-depth interviews, proved advantageous in capturing nuanced perspectives from industry experts. These qualitative insights provided a rich understanding of both the practical applications and the limitations of AI in the context of energy management.

The research question is answered by the findings. The evidence suggests that while AI technologies are capable of optimizing energy consumption and improving operational efficiencies, their energy demands remain a critical concern. The divergent experiences of the interviewees indicate that the effectiveness of AI in promoting sustainability is highly dependent on the strategic integration of renewable energy sources and energy-efficient infrastructures within organizations.

To further validate these preliminary findings, a subsequent survey is planned to target a broader sample of employees – including managerial staff – to analyse and statistically validate the exploratory insights generated by these interviews.

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Work-Related Stress and Company Size – IT Industry in Croatia

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Work-related stress is an inevitable aspect of the business environment, making studies in this field crucial for both scientific and practical contributions. This paper examines the causes and levels of stress among employees in Croatia's IT industry. The study aims to define stress levels in the IT sector and investigate how company size impacts stress. The stress levels were assessed through a questionnaire using the PSS-10 scale for measurement. The research sample comprised 121 respondents, and the data was statistically analyzed through ANOVA. The results did not indicate any significant differences in stress levels based on company size, suggesting that company size does not impact stress levels. The study identified that the most common causes of stress in the Croatian IT industry were: the number of job tasks, interpersonal relationships among coworkers, and limited promotion opportunities. Recommendations for reducing stress levels in the Croatian IT industry include managing work-life balance and providing continuous management support.

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1 Introduction

In today's world, individuals often experience stress due to various sources, with work being one of the most significant. Workplace stress can profoundly impact employees and, consequently, the overall performance of a company. The IT industry has experienced substantial growth in Croatia and globally in recent years. However, this expansion often leads to significant changes in the workplace, which can induce stress among employees. The demand for IT professionals remains stable, making this industry one of the safest for employment (Rouse, 2024). The IT sector in Croatia is growing at a rate faster than the national economy (Croatian Chamber of Economy, 2024). According to the National Classification of IT Industry Activities, there were 9,143 registered IT companies in Croatia in 2025, comprising 19 large companies, 84 medium-sized companies, and 9,040 small and micro companies (FINA, 2025). Therefore, it is essential to identify the stress factors affecting employees in the IT industry to minimize stress within these companies.

The literature review identified a gap in existing research regarding the examination of how company size affects employee stress levels in the IT industry. The current study has explored the effect of company size on stress levels in the IT sector in Croatia for the first time. This study aims to investigate whether company size impacts stress levels among employees in this sector. The following research questions were defined:

RQ1: What is the average stress level of employees in IT companies in Croatia?
RQ2: Is there a difference in employee stress levels depending on the size of the company? RQ3: What are the main factors contributing to stress among employees in the IT industry?

Primary research was conducted to collect data on the stress levels of employees in the IT industry. The stress scale developed by Cohen et al. (1983) was employed to ensure the validity of the research. This study has significant scientific and practical contributions in examining the impact of company size on stress levels and emphasizing the most critical stress factors for employees, respectively. The paper is structured as: introduction, literature review, methodology description, research results, and a conclusion summarizing the key findings.

2 Literature review

Previous studies have encountered challenges when formulating a general theoretical conception of stress, and numerous definitions have been presented (Mihailović, 2003). Mihailović (2003) defined stress as, "a psychophysical state in which a person finds themselves in difficult circumstances and situations." In a medical or biological context, stress is a physical, mental, or emotional factor that induces tension (Davis, 2021). Stress denotes the physiological, psychological, and social reactions of the organism to various stressors, which can be internal or external and possess both positive and negative aspects (Matulović, Rončević, and Sindik, 2012). Aslan et al. (2025) asserted that work stress negatively impacts employees' physical and mental health, potentially leading to conditions such as burnout, anxiety, depression, and reduced productivity. Stress can be described as a condition in which individuals face workplace demands that they cannot meet, making success feel unattainable (Helia et al., 2025). Depending on each employee's mindset and perspective, stress can hinder their achievements and work performance (Helia et al., 2025). Kumar et al. (2021) defined job stress as, "the pressure that an employee feels due to employment-related factors." According to Lučanin (2014), stress factors can be events or circumstances that individuals react to and can be categorized into three main groups: physical, psychological, and social.

Kavivarshini and Harihara Sudhan (2023) examined factors influencing employee stress levels with a sample of 100 IT employees from Chennai, India. The results indicated that work-related stress affects all employees regardless of age, and there is a statistically significant difference between employees' age and the amount of stress they experience (Kavivarshini and Harihara Sudhan, 2023). A study by Ahmad et al. (2018) examined the stress levels of 125 managers in the textile industry in Pakistan, using the Perceived Stress Scale (PSS-10). The results showed that 86.4% of respondents experienced work-related stress, with 46.3% classified as severely stressed, with an average PSS score of 15.98 (Ahmad et al., 2018). Chaillet et al. (2025) conducted research with a target population of 358 medical interns from a French university hospital. The results indicated an average stress level of 19.86, with agreeableness, neuroticism, and the risk of workaholism associated with higher perceived stress levels (Chaillet et al., 2025). Conversely, having time for hobbies and conscientiousness were linked to lower perceived stress levels. Colato et al. (2025) researched 388 IT professionals in the US, revealing an average level of 15.1,

classified as moderate stress. Lee (2023) investigated construction employees and revealed that employees from both large and small construction companies experienced similar stresses. This study identified a lack of research related to stress levels and whether firm size impacts stress levels based on different organizational characteristics. However, Lai et al. (2013) examined the direct association between firm size and employees' experiences of job stress, finding no supporting evidence for a side effect. Based on the literature review and research questions, the research hypothesis is as follows:

H1 Company size does not impact employee stress levels.

3 Methodology and results

The primary research was conducted using a survey questionnaire among participants working in the IT industry. The survey was created using Google Forms and consisted of five demographic questions, six general questions about stress, and a stress measurement scale to assess the stress level variable. The PSS-10, adapted from Cohen et al. (1983), has also been previously used by Ahmad et al. (2018), Chaillet et al. (2025), and Colato et al. (2025). The PSS-10 is a 10-question scale designed to determine the extent to which participants perceive their lives as unpredictable, uncontrollable, and overloaded. The scale includes questions about the current level of stress experienced by the participants. The total PSS-10 score ranges from 0 to 40, with higher scores indicating higher stress levels (Chaillet et al., 2025). The survey was anonymous and conducted in September 2024. It was distributed via social networks using purposive and chain sampling. To ensure the validity of this sampling method, two elimination questions were included to exclude the unemployed individuals and those not working in the IT industry.

Of the 125 questionnaires collected, 121 were included in the analysis, as four did not meet the requirement for employment in the IT industry. Among the 121 participants, 61.2% identified as male, 38% as female, and one participant identified as neither male nor female. These results reflect the underrepresentation of women in the IT sector. The majority of responses came from participants aged 18 to 30, accounting for 47.9%, followed by 43.8% aged 31 to 40, and 5% aged 41 to 50. The smallest group consisted of participants aged 51 to 60, at 3.3%. When asked, "Have you faced stress at work?", 83.5% of the participants answered positively, 9.1%

answered negatively, while the remaining 7.4% were uncertain. Regarding sources of stress, 60.3% of the participants indicated that excessive workload was the primary source of stress. Additionally, 57.9% of participants pointed to interpersonal relationships as a significant source of stress, while21.5% identified low salary as a stress factor.

The most common causes of stress included: high work intensity, tight deadlines, and high task responsibility. According to participants, 60.3% cited excessive workload as a key stress factor, while interpersonal relationships and overtime were also identified as significant contributors. Furthermore, 36.4% of participants highlighted the lack of flexibility in work as problematic, while 26.4% believed that the absence of clear opportunities for professional development increased their stress levels.

ANOVA was employed to test the hypothesis H1. The stress level and company size served as the dependent and independent variables, respectively. The results of the PSS stress level according to company size are presented in Table 1. Cohen et al. (1983) defined three levels of stress: low (scores from 0 to 13), moderate (scores from 14 to 26), and high (scores from 27 to 40). The results revealed an average PSS-10 score of above 20, indicating a moderate level of stress among the participants.

Table 1: PSS-10 score

	Micro companies (SD)	Small companies (SD)	Medium companies (SD)	Large companies (SD)
PSS score	22.382 (4.930)	22.514 (2.241)	21.806 (4.153)	23.500 (4.733)

ANOVA was not conducted for large companies due to the insufficient number of responses (fewer than 30). A single-factor ANOVA was chosen because we have one independent variable. Table 2 presents the ANOVA results. The p-value exceeded the usual significance threshold of 0.05 (0.895860082). These results confirm insufficient evidence of statistically significant differences between the average values for micro, small and medium-sized companies. The findings are in line with a previous study by Goodin (2020). Conclusively, no significant differences in stress levels were found among companies of different sizes, indicating that stress levels do not depend on company size, confirming the hypothesis H1.

Table 2: ANOVA Test Results

Summary						
Groups	Count		Sum	Average	Variance	
Micro	10		761	76.1	184.76	
Small	10		788	78.8	154.62	
Medium	10		785	78.5	255.61	
ANOVA						
Source of Variation	SS	df	MS	F	p-value	F-crit
Between Groups	43.8	2	21.9	0.110420168	0,895860082	3.354130829
Within Groups	5355	27	198.3333333			
	5398.8	29				

4 Conclusion

The findings of this study concluded that company size does not affect the level of stress among employees in IT companies. However, the current level of stress experienced by participants may vary depending on specific questions. The results indicated that employees in the IT industry are significantly exposed to stress. Excessive workloads and interpersonal relationships were identified as the most significant sources of stress for employees in IT companies. These findings suggest that IT companies should focus on developing effective human resource management strategies that emphasize these factors. Rapid changes within the workplace and a competitive environment undoubtedly contribute to stress. Additionally, the shift toward remote work and increased reliance on digital tools have become defining features of modern organizational life, particularly in the IT sector. For IT professionals, the cognitive load is high due to the need to manage and process complex information, and individuals are frequently required to learn and adapt to new digital tools or systems, leading to diminished performance and increased stress (Xie and Yang, 2025). However, activities related to human resource management can help maintain stress levels at an acceptable level, preventing stress from reducing employee satisfaction, impairing their health, and ultimately negatively affecting company performance. These insights provide valuable recommendations for the professional community. Additionally, Aslan et al. (2025) suggest that company leaders and human resources professionals should consider

adopting leadership styles, such as democratic leadership, which foster positive workplace climates to mitigate stress.

The results did not indicate a difference in stress level in micro, small, and medium-sized companies, aligning with findings from Lee (2023) in the construction industry. However, these findings could not be compared due to the lack of similar studies. The insignificant results could be explained by other factors that may influence stress levels, including organizational culture, HR practices, and individual factors like age, position, or personality. This area represents a area for future research, and these results provide intriguing scientific insight. Therefore, the PSS-10 score indicated a higher average level of stress in the Croatian IT industry, compared to studies by Ahmad et al. (2018), Colato et al. (2025), and Chaillet et al. (2025). These the importance of validating and monitoring stress levels in the IT industry.

It is essential to consider the limitations of the study when interpreting the results. The insufficient number of employees from large companies precluded conducting the ANOVA test for this group. Additionally, expanding the research sample would be necessary to obtain more reliable results and ensure a high level of representativeness. Furthermore, this study is also limited by a lack of control variables (e.g., job role, experience level). When interpreting the results, it is crucial to consider the stated limitations and how they relate to the studied population.

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Contemporary Teaching and Learning Strategies for Future Competencies

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When service learning meets sustainability learning, new integration benefits arise within curricular and extracurricular activities in higher education. By exploring the approach of integrating service and sustainability learning, their potential to enhance student engagement and foster a sustainability culture is revealed. Active learning methodologies, which include digital technology inspired innovations with problem-based learning and community engagement, offer to significantly improve students' understanding of sustainability while developing competencies for future careers. Importance of hybrid pedagogies that intertwine service and sustainability learning with traditionally introduced academic content form contemporary teaching and learning strategies, demonstrating their positive impact on students' engagement and sense of affiliation to community while contributing to building a resilient and sustainable environment. Additionally, the role of extracurricular activities in promoting entrepreneurship as a self-transcendence, self-efficacy and desirable business behaviour among students is evident, illustrating how such activities can enhance their competencies. The need for educators to adopt facilitative roles in creating supportive learning environments by advocating for professional development and fostering teachers to effectively implement these contemporary teaching strategies is explored as well. This paper aims to provide a conceptual framework for integrating service and sustainability learning into educational practices, thereby preparing students to tackle complex sustainability challenges.

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1 Introduction

Contemporary challenges related to environmental sustainability, including climate change, global warming, biodiversity loss, and environmental pollution, as well as social and economic challenges such as inequalities in employment and income opportunities, access to quality education, and others, require specialized knowledge and skills essential for their resolution. Environmental, economic, and social sustainability cannot be learned as a fixed set of solutions but rather as a process of developing the knowledge and skills necessary to address related challenges and manage them responsibly.

Given the rapid pace of urbanization around the world and the ubiquity of environmental problems, flexible and sensitive approaches that put communities at the center become crucial to recognizing and understanding their needs and improving their context (Cervantes & Hinojosa, 2022). Service learning and sustainability learning are two different but closely related approaches to teaching and learning that bring together sustainability and community issues and require synergistic thinking and action. Sustainability learning implies an approach to teaching and learning that deals with sustainable principles, taking into account different models related to sustainability such as the Sustainable Development Goals (SDGs), Triple Bottom Line, ESG, and RE(use/duce/cycle). Service learning is a teaching and learning approach that intentionally applies knowledge and skills to develop service-based solutions, foster community engagement, and strengthen social connections, ultimately promoting civic responsibility and active citizenship (Cervantes & Hinojosa, 2022).

Service learning and sustainability learning engage students, teachers, and communities through academic content, community activities, and reflection, fostering civic involvement and personal growth (Mitchell, 2020), (Ruiz et al., 2024). These approaches align higher education with societal needs by integrating community engagement, structured reflection, and academic-community partnerships. Recognized in *the European Sustainability Competence Framework* (2022), they support Green Comp's four key areas: Embodying sustainability values, Embracing complexity in sustainability, Envisioning sustainable futures, Acting for sustainability (European Commission, n.d.). The 2022 *Council Recommendation on learning for the green transition and sustainable development* further emphasizes policies

promoting interconnected learning across environmental, economic, and social dimensions for a sustainable future (Council Recommendation of 16 June 2022 on Learning for the Green Transition and Sustainable Development, 2022).

This research, aims to provide insights into learning outcomes and objectives, methods and approaches, as well as the evaluation and impact of service and sustainability learning approaches in higher education. To illustrate best practices, case study based examples describe how these teaching approaches are integrated into both curricular and extracurricular activities.

2 Theoretical Background / Literature Review

Service learning is an innovative pedagogical approach that bridges the classroom and the community, positioning students as key agents in fostering local development (Shahbani et al., 2019). Grounded in John Dewey's pragmatic theory, service-learning emphasizes experiential education and active civic engagement, equipping students with the skills and mindset necessary to navigate societal changes and challenges (Said et al., 2019).

Service learning is based on identifying community needs, where students collaboratively develop innovative solutions to improve quality of life, often based on implementing digital technologies. This holistic approach enhances skills and knowledge through active service initiatives, encouraging critical thinking, action, and reflection. It also engages NGOs, local authorities, industry, and academia to support service-learning projects (Shahbani et al., 2019). Service learning is an educational model where students participate in structured activities to address community needs while reflecting on services. It enhances their understanding of course content, broadens their disciplinary perspective, and fosters civic responsibility (Lounsbury & Pollack, 2001), (Mayhew & Engberg, 2011).

According to Dewey, service learning includes six steps typical for investigative learning approaches (a) encountering a problem; (b) formulating questions; (c) gathering information; (d) formulating hypotheses; (e) testing hypotheses, and (f) making justified claims (Mayhew & Engberg, 2011). As a paradigm, service learning is based on connection, creativity, community, and complexity and is used to develop students' thinking skills through applied community engagement projects,

which combine interactivity and interconnectedness, innovation and insight, and inspiration and intuition, integrative and interdisciplinary thinking (Karakas & Kavas, 2009).

Sustainability learning is a teaching and learning approach that prioritizes the well-being of future generations while emphasizing sustainable economic, environmental, and social principles. It is a transdisciplinary and multi-level concept in which educational objectives are aligned with sustainable development goals (Hansmann, 2010).

Higher education institutions can integrate SDGs into their work in three key ways: (1) Recognition, (2) Opportunistic Alignment, and (3) Organizing and Embedding Principles (Angelaki et al., 2024). Recognition involves identifying and assessing existing university initiatives that contribute to sustainable development. This process not only highlights best practices but also serves as a catalyst for further action. Opportunistic Alignment refers to the integration of sustainability-related issues into specific activities and academic programs, leveraging opportunities as they arise. Organizing and Embedding Principles entail systematically incorporating SDG principles into university governance, ensuring their presence across policies, management structures, and institutional frameworks (Angelaki et al., 2024).

3 Methodology

Aligned with the areas and competencies outlined in the European Sustainability Competence Framework and guided by Bloom's taxonomy of learning outcomes, a literature review was conducted to identify general learning outcomes associated with service and sustainability learning. Furthermore, key components of service and sustainability learning were analyzed, including teaching and learning resources, the learning environment, pedagogical processes, instructional methods and techniques, stakeholder involvement, as well as evaluation and feedback mechanisms. The analysis included articles retrieved using the research query ("service learning" OR "sustainability learning") AND ("teaching practices" OR "learning practices"), filtered by topic, taking into account the title, keywords, and abstract. Only articles available in English were considered. Through case study analysis, this research presents two examples of service and sustainability learning, one integrated into a curricular program and the other within an extracurricular program.

4 Results

This research seeks to provide stakeholders in the academic community with a comprehensive analysis of learning objectives and outcomes, processes of planning, preparation and implementation, learning environment, teaching and learning methods and techniques as well as the broader impact of service and sustainability learning within academic programs, as previously done by Munna & Kalam, 2021. Furthermore, it offers evidence-based guidelines for integrating these approaches across diverse curricular and extracurricular higher education programs. All the elements are described in the next sections, following the structure of our findings as shown in Figure 1.

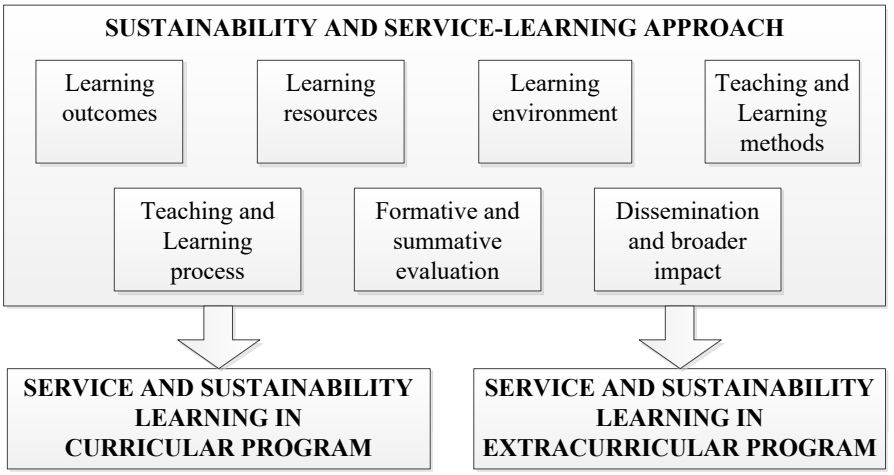

Figure 1: Overview of key elements of the sustainability and service learning approach

4.1 Sustainability and service-learning approach

The learning outcomes for service learning and sustainability, identified through a literature review, align with the competence areas of the European Sustainability Competence Framework. These outcomes, categorized into four key areas, are presented in Table 1.

Table 1: Learning outcomes of service and sustainable learning

Embodying Sustainability Values	Cultivate an understanding of social inequalities and the necessity for a more equitable society while also fostering awareness of environmental, economic, and social challenges (Mayhew & Engberg, 2011), (Yusof et al., 2020)
	Internalize the values of sustainability by engaging in practical actions and reflecting on community needs (Howard et al., 2010), (Shahbani et al., 2019), (Said et al., 2019), (Yusof et al., 2020), (Souza-Alonso et al., 2024), (Hong et al., 2024)
Embracing Complexity in Sustainability	Analyze the interplay between social, economic, and ecological systems and their collective impact on community dynamics (V. M. Smith, 2003), (Mayhew & Engberg, 2011), (Ruiz et al., 2024)
	Apply critical thinking to understand complex community problems and environmental, economic, and social issues (Karakas & Kavas, 2009), (Shahbani et al., 2019), (Yusof et al., 2020), (Ruiz et al., 2024), (Hong et al., 2024)
Envisioning Sustainable Futures	Develop the ability to anticipate future environmental, economic and social challenges (Howard et al., 2010), (Shahbani et al., 2019), (Said et al., 2019), (Yusof et al., 2020), (Ruiz et al., 2024)
	Experiment with innovative solutions in sustainable development and community (Karakas & Kavas, 2009), (Souza-Alonso et al., 2024)
Acting for Sustainability	Initiate and participate in social initiatives for sustainable development (Shahbani et al., 2019), (Souza-Alonso et al., 2024), (Said et al., 2019)
	Demonstrate civic responsibility through concrete actions in the community and environmental, economic, and social actions (Karakas & Kavas, 2009), (Mitchell, 2020), (Ruiz et al., 2024)

Learning resources encompass a variety of teaching materials, including supplementary literature that elaborates on economic, environmental, and social sustainability, as well as contemporary social issues. These resources may include scientific articles, analytical reports, videos, prepared multimedia content, and other relevant visualization materials (Mayhew & Engberg, 2011).

The learning environment should be structured to foster a safe, inclusive and supportive atmosphere, facilitate effective communication with students, and cultivate meaningful relationships with stakeholders. Particular emphasis is placed on engagement with stakeholders whose challenges are being analyzed (Shahbani et al., 2019).

Teaching and learning methods incorporate a diverse range of approaches, including reflective activities, essays discussions, observation, mapping, interviews, field visits, prototypes and direct interaction with stakeholders (Cervantes & Hinojosa, 2022), (Pederson et al., 2018). Additionally, the pedagogical approach prioritizes shorter

instructional segments, commonly referred to as mini-lectures (Day & Lane, 2014), while placing greater emphasis on teamwork and fieldwork.

The learning and teaching process includes planning, preparation, and implementation. Effective planning requires university leadership to raise awareness of sustainability and community engagement, define instructional strategies, design relevant curricula, and structure activities. Preparation involves teacher training, while implementation follows a phased approach: motivation, problem identification, diagnosis, planning, design and prototyping, execution or pitching, documentation, systematization, communication, and evaluation (Maravé-Vivas et al., 2022). Optimizing student learning and time-on-task is crucial, ensuring clear guidelines on timelines, deadlines, and deliverables.

For evaluating students' work, a combination of formative and summative assessments is recommended (E. Smith et al., 2023). Evaluations should encourage diverse demonstrations of understanding, such as raising awareness of social, economic, and environmental issues, group collaboration, and interpersonal skill development (Borkoski & Prosser, 2020). Moreover, reliance on standardized assessments should be minimized due to potential biases (E. Smith et al., 2023).

The dissemination and broad impact of sustainability and service learning are fostered through the exchange of best practices, the development of a training and education network (Souza-Alonso et al., 2024), and the meaningful exchange of ideas in both formal and informal community settings, as well as through active collaboration with the community.

4.2 Service and sustainability learning in curricular program

As part of the curricular program, service and sustainability learning were integrated through the Global Goals Jam (Global Goals Jam, n.d.) event in the course Operations Management. Students were tasked with identifying a local community problem and proposing a solution that aligns with sustainable development principles and social responsibility, supported by digital technologies.

The implementation process included short lectures and discussions, the Global Goals Jam mini-competition, the evaluation of final concepts and prototypes, and dissemination. Lectures and discussions covered key topics in environmental, economic, and social sustainability, introducing students to sustainability concepts and showcasing best practices.

The mini-competition was an intensive two-day event structured into four sprints, where students worked collaboratively to develop sustainable and socially responsible concepts. The four sprints were: 1) Explore it!, 2) Respond to it!, 3) Make it!, and 4) Share it!. The estimated duration of each sprint was 90 minutes. Finally, student teams pitched their solutions through short presentations as well as concept and prototype demonstrations, which were carefully reviewed and evaluated by a "jury" consisting of stakeholders like academic and professional evaluators as well as peers.

To further expand their ideas and inspire broader community engagement, students presented their proposed solutions at conferences and events focused on sustainable development.

4.3 Service and sustainability learning in extracurricular program

As an extracurricular activity, an Erasmus+ Blended intensive program (BIP), titled „Transform to sustain: Sustainable future enabled by digital transformation", was conducted in a hybrid format, through collaboration of five higher education institutions (Faculty of Organization and Informatics, University in Zagreb, 2023). Online sessions over four weeks enabled students to form international, multidisciplinary teams and develop SDG-aligned digital solutions. A week-long onsite program featured interactive workshops complementing online learning with hands-on activities. Students designed digital innovations, refined prototypes, pitched ideas, and explored digital technologies like robotics. A field trip to a remote island allowed testing with real users, providing valuable feedback.

The program aimed to introduce participants to creative methods for customer needs analysis, business improvement, and sustainable digital transformation. It integrated four key business development concepts: Digital Transformation, Sustainable Development, Digital Technologies (AI & Robotics), and Business

Process Management. Teaching methods included problem-based learning, gamification, teamwork, and project-based tasks, fostering a collaborative environment. As the conclusion of the program, student teams presented their solutions, receiving valuable feedback from teachers and peers. Learning outcomes that students achieved were: (1) Comprehend and enforce creative methods, techniques and tools for customer needs analysis and innovative ideas creation, (2) Understand and apply the basic concepts of artificial intelligence, particularly deep neural networks and (3) Propose a new digital and sustainable business model of an organization.

5 Conclusions

Integrating service and sustainability learning into both curricular and extracurricular programs requires significant effort from educators. However, the benefits for all stakeholders - students, teachers, and the broader community - are substantial. One of the primary challenges for educators is finding ways to embed service and sustainability learning within the curriculum while ensuring alignment and coherence across content areas. Additionally, the planning and execution of activities demand careful spatial and temporal coordination. For students, this approach is not only engaging and dynamic but also enhances their understanding of academic content in innovative ways. Moreover, it fosters the development of digital competencies, essential soft skills such as teamwork, critical and creative thinking, and social awareness. By engaging with real-world challenges, students become more attuned to the needs of their communities and learn to approach social, economic, and environmental issues with a problem-solving mindset, positioning themselves as catalysts for meaningful change. Although the proposed integrated approach proves valuable in many educational programs, its application tends to be limited in strictly theoretical disciplines or those lacking a practical, real-world component. Implementing this approach faces organizational and practical challenges, primarily due to a lack of relevant knowledge and skills among educators, many of whom may not have a background in sustainability. Additionally, limited infrastructural capacity, such as inadequate access to appropriate technologies, physical space, and available time, can significantly hinder the development of effective, practice-based solutions that contribute to society and support sustainable practices.

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Impact of Fiscal Policies on the Economic Growth of Kosovo, Albania and North Macedonia

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The main objective of this research is to analyze the impact of fiscal policy on economic growth, for the Republic of Kosovo, Albania and North Macedonia and the period 2000-2023. The data used in this research are secondary data and are generated from official data published by the World Bank and the International Monetary Fund. The results of this study were analyzed through the Stata program, and data testing was carried out through standard multiple regression analysis, Hausman Taylor test, GEE model, GMM model, fixed effect and random effect. Based on the results, we may conclude that the increase in income, gross debt, and government expenditures positively affect the GDP of Kosovo, Albania and North Macedonia, whereas inflation negatively affects economic growth. There is a positive relationship between income, gross debt, government spending and GDP. This research aims to analyze the impact of fiscal policy on the economic growth of the Republic of Kosovo, Albania and North Macedonia for the period 2000-2023. As such, this research can be used as a basis for future work in this area.

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1 Introduction

Fiscal policy and its proper management are among the most important and vital components for economic development of the country. It also plays a crucial role in addressing social and economic inequality within the population. Through fiscal policy mechanisms, governments aim to support and promote economic growth.The role of fiscal policy in the long-term growth process has been crucial in macroeconomics since the emergence of endogenous growth models (Paparas, D., Richter, C. and Paparas, A., 2015)

The purpose of this research is to analyze the impact of fiscal policies on the economic growth of Kosovo, Albania and North Macedonia for the period 2000-2022. To further specify this research, the econometric model was built, where the main independent variable is the GDP as the main indicator of economic development, whereas the dependent variables in this model are: inflation, income, gross debt and government spending.

The Republic of Kosovo as a new state, independent from 2008, continues to work on the consolidation of fiscal policy and their compatibility with European Law, practices and standards. Stimulating economic development continues to be a very important challenge for the Republic of Kosovo.

Countries like North Macedonia that aim to boost economic development can achieve this through fiscal policies that include stimulating domestic and foreign investments, moderate taxes for businesses, investments in infrastructure, healthcare, and education, thereby promoting the creation of new jobs and consequently economic growth.

Both countries, North Macedonia and Albania Albania are facing challenges in managing public debt, may encounter fiscal difficulties in the future if effective measures are not implemented to reduce it. To avoid these challenges, it is necessary to adopt measures such as cutting inefficient expenditures, combating the informal economy, diversifying revenue sources, and promoting innovations that stimulate economic development.

2 Literature review

The research carried out in North Macedonia examines how public debt affects GDP growth in the Republic of Macedonia. The OLS fitted line revealed a negative correlation between public debt and economic development in the country. Based on the VECM results and co-integration test there exists a long run relationship between public debt and real economic growth. There is an ongoing link between public debt and actual economic development. Empirical data show a negative association between initial debt and long-term growth. Increasing the initial public debt by 10% typically leads to a 1.3 percentage point decrease in real GDP growth (Sadiku, L., Bexheti, A., & Sadiku, M., 2018, May).

The study conducted by Velichkovska, K., & Sadiku, L., (2019) examines how government expenditures affect economic growth in the Republic of Macedonia from 2000Q1 to 2016Q4. The analysis shows that increasing government spending has a beneficial impact on GDP, supporting the idea of expansionary fiscal policy. Reforming the country's public expenditure system, particularly increasing capital expenditures, is crucial for driving economic growth.

Both Macedonia and Romania have a lengthy history of a relationship between governmental debt and GDP. This demonstrates that shifts in public debt have a consistent impact on economic development. In the short run, there appears to be an inverse link between rising public debt and GDP. This indicates that increased public debt may limit economic development in the short term (Moysova Kyoseva, N., 2016).

A paper conducted by (Shijaku G. &., 2013) analyzes the effects of fiscal policy on the economic growth of Albania. The research finds that the policies of the Albanian government on income have a higher effect than the government's policies on government spending. In this research, tax revenues are categorized into distorting and non-distorting, whereas the government expenditures into productive and non-productive. The research also finds that the increase in public debt has a negative effect on the economic growth of Albania.

The findings of the research conducted by the Petrevski, G., Trenovski, B., & Tashevska, B, (2019) study the macroeconomic effects of fiscal and monetary policies in Macedonia and their interactions during the years 2000-2014. The main findings of this research are below: first, an increase in public spending results in lower economic activity, higher public debt and loss of foreign exchange reserves; Second, an increase in public revenues has positive output effects coupled with rising prices, increased foreign exchange reserves and a modest reduction in public debt; Third, a central bank interest rate increase produces conventional negative effects on economic activity, followed by a fall in the price level; Fourth, monetary and fiscal policies act as strategic substitutes; And fifth, our estimates of fiscal multipliers imply non-Keynesian fiscal policy effects.

According to research done by (Gllogjani, 2022), government revenues, indirect taxes, government expenditures, current expenditures, fiscal deficit, exports, imports, and higher education have a significant impact on economic growth.

3 Methodology

The main objective of this research is to analyze the impact of fiscal policies on the economic growth of Kosovo, Albania and North Macedonia for the period 2000-2023. So this research shows what impact fiscal policies have on the economic growth of the countries of Kosovo, Albania and North Macedonia. The main variables of this research are: Gross Domestic Product (GDP), Inflation (INFL), Income (REV), Gross Debt (GDEBT), Government Expenditure (Gex). The scientific methodology that has been applied in this study is the quantitative method. The data that will be used in the research are secondary data and have been generated from official data published by the World Bank, the IMF and the Kosovo Statistics Agency. The results of this study will be analyzed through the Stata program. The research questions of this study are:

1. How does the change in inflation affect the GDP growth of Kosovo, Albania and North Macedonia for the period 2000-2023?
2. How does the change in gross debt affect the GDP of Kosovo, Albania and North Macedonia for the period 2000-2023?
3. What is the relationship between inflation, income, gross debt, government spending, and GDP?

The main hypotheses of this research are:

H_0 - the increase in income, gross debt, government spending negatively affects the GDP of Kosovo, Albania and North Macedonia.
H_1 - the increase in income, gross debt, government spending does not negatively affect the GDP of Kosovo, Albania and North Macedonia.

Table 1: Description of the variables included in the econometric models

Variables	Variable description	Data source
Dependent Variable (Y)	Produkti i Brendshëm Bruto (GDP)	(World Bank, Annual Reports, Time Series 2000-2023, n.d)(World Bank, Annual Reports, Time Series 2000-2023, n.d) https://data.worldbank.org/
Independent Variable (X2)	Inflation (INFL)	(World Bank, Annual Reports, Time Series 2000-2023, n.d)(World Bank, Annual Reports, Time Series 2000-2023, n.d) https://data.worldbank.org/
Independent Variable (X3)	Revenu (REV)	(International Monetary Fund, Time series 2000-2023, n.d)(World Bank, Annual Reports, Time Series 2000-2023, n.d) https://www.imf.org/en/Home
Independent Variable (X4)	Gross Debt (GDebt)	(International Monetary Fund, Time series 2000-2023, n.d)(World Bank, Annual Reports, Time Series 2000-2023, n.d) https://www.imf.org/en/Home
Independent Variable (X4)	Government expediture (GEx)	(World Bank, Annual Reports, Time Series 2000-2023, n.d)(World Bank, Annual Reports, Time Series 2000-2023, n.d https://data.Worldbank.org/

Source: Data processing by author (2024)

To test the hypotheses of this study, the econometric model must be built to prove these hypotheses. This econometric model will look like the following:

$$GDPit = \beta_0 + \beta_1 INFLit + \beta_2 REVit + \beta_3 GDEBTit + \beta_4 GExit + \gamma it$$

Where:
GDP *- Gross Domestic Product*
INFL *- Inflation*
REV *- Revenue*
GDebt *– Gross Debt*
GEx *- Government Expenditure*

stochastic variables (other factors not considered in the model)
i *– code and* ***t*** *– time period*

4 Results

In this section of the research, will be analyzed the findings and the results of the study titled

"Impact of fiscal policy on the economic growth, for the Republic of Kosovo, Albania and North Macedonia will be interpreted. The data used in this study are secondary data processed in the STATA program and are presented within the panel data. This testing will be done using standard multiple regression analysis, fixed effect model, random effect model, Hausman Taylor Estimation, GMM Model, Arellano Bond Estimation, GEE model. In Table 2 we find summarized the results of the econometric model which will be interpreted through the GMM Model.

Table 2: Summary empirical results from the econometric model

Variables	Linear Regression	Random Effeccts Generalized Least Squares (GLS) Regression	Fixed Effects Regression	Hausman Taylor Regression	GEE Model	GMM Model
GDP	-	-	-	-	-	-
Inflation_ interpolate	.7332434 (0.000)***	.7332433 (0.000) ***	.7332433 (0.000) ***	.7332433 (0.000) ***	.7332433 (0.000)***	-.3804178 (0.003)***
Revenue_ interpolate	1.284205 (0.000)***	1.284205 (0.000) ***	1.284205 (0.000) ***	1.284205 (0.000)***	1.284205 (0.000)***	2.201331 (0.000)***
GrossDebt_ interpolate	-.070662 (0.054)**	-.070662 (0.049) **	-.070662 (0.059) **	-.070662 (0.052) **	-.070662 (0.045)**	.5075103 (0.000)***
GovernmentExpediture_ interpolate	-.1846434 (0.095)*	-.1846434 (0.089) *	-.1846434 (0.101)	-.1846434 (0.092) *	-.1846434 (0.083)*	1.6442 (0.072)*
R Square	0.5077					
Adj. R^2	0.4719					

Source: Author's calculations in Stata (2024)
significance level 10%
*** significance level 5%*
**** 1% significance level*

$$GDPit = \beta_0 + \beta_1 INFLit + \beta_2\ REVit + \beta_3\ GDEBTit + \beta_4 GExit + \gamma it$$
$$GDPit = \beta_0 - 0.3\ it + 2.20\ it + 0.50\ it + 1.64\ it + \gamma it$$

β_1INFL - if Inflation increases by one unit, keeping other factors constant, then GDP will decrease by 0.3 units. This statement is true at the 5% significance level, because the significance level is 0.003 < 0.05.

β_2REV - if income increases by one unit holding other factors constant then GDP will increase by 2.20 units. This statement is true because the significance level is 0.000 < 0.05.

β_3GDEBT - if Gross Debt increases by one unit keeping other factors constant then GDP will increase by 0.50 units. This statement is true because the significance level is 0.000 < 0.05.

β_4GEx - if Government Spending increases by one unit holding other factors constant then GDP will increase by 1.64 units. This statement is true because the significance level is 0.072 < 0.10

The R Square correlation coefficient is 50.7%, so the correlation between dependent and independent variables is 50.7%. While the coefficient of determination Adj. R2 is 47.19%, so 47.19% of the dependent variables explain the independent variable.

Through the results of the multiple standard regression analysis using the GMM Model, we can come to the conclusion that all variables are significant and have statistical significance and have an impact on the GDP of Kosovo, Albania and Macedonia. Based on the results, we can conclude that the increase in income, gross debt, and government expenditures have a positive effect on the GDP of Kosovo, Albania and North Macedonia. So the hypothesis H_0 is rejected and H_1 is accepted.

5 Discussion

The findings on the impact of inflation align with general economic theory and numerous other studies in the field. Additionally, the observed correlations, despite variations in intensity, are consistent with previous research Bexheti, A., Sadiku, L., & Sadiku, M, (2018). However, certain sector-specific correlations do not exhibit similarly positive results, such as the relationship between inflation and education expenditures (Kamberaj, 2024, July 1). Moreover, the stronger impact of income (2.2 units) compared to expenditures (1.64 units) does not align with fiscal multipliers

and requires further analysis to determine the underlying reasons and causality. These differences may stem from the low institutional capacity, lack of transparency, and inefficiency in public expenditures within the respective countries. A particularly challenging finding relates to the impact of public debt, especially in North Macedonia and Albania, where debt levels have surpassed the optimal debt-to-GDP ratio (52-54%), as identified in other research papers Fetai, B., Avdimetaj, K., Bexheti, A., & Malaj, A, (2020). Meanwhile, a study conducted by the Riinvest Institute concluded that Kosovo should consider restructuring budget expenditures to encourage investments in education, health, and research in order to boost competitiveness and economic growth (Riinvest Institute, 2024).

6 Conclusions

Based on statistical results generated through calculations in Stata using the GMM model, it is evident that inflation negatively affects the economic growth of Kosovo, Albania, and North Macedonia. High inflation can create uncertainty in the investment market and, in addition, the rise in the general price level will reduce the consumption, thereby negatively impacting economic growth. The statistical results also indicate that gross debt has a positive effect on the economic growth of Kosovo, Albania, and North Macedonia for the period 2000-2023, but not at all threshold levels. If gross debt is utilized for investments development projects in infrastructure, and policies aimed at economic recovery, it can stimulate economic growth. The study finds that increases in income, gross debt, and government expenditures positively influence the GDP of these countries. This research suggests the following key recommendations: The governments of Kosovo, Albania, and North Macedonia should prioritize strengthening institutional capacity and increasing investments in infrastructure, education, healthcare, and other critical sectors for economic development. However, it is crucial to ensure that gross debt remains under control, particularly in the cases of North Macedonia and Albania. During economic downturns, governments should implement stronger fiscal policies and adopt countercyclical fiscal measures to sustain economic activity and prevent downturns.

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Gender Equality and the ESG Performance: An Index-Based Comparative Analysis of Hungary, Czechia, Poland, and Spain With a Focus on the Gender Pay Gap

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This paper examines the environmental-corporate-societal performance of Hungary, Czechia, Poland, and Spain through an index-based approach, incorporating gender equality as a key dimension. The research aims to assess how gender disparities, particularly the gender pay gap, influence sustainability-related performance in these countries. The methodology employs a composite index integrating environmental, corporate, and societal indicators, weighted according to multiple scenarios to ensure robustness. The findings reveal significant variations among the analysed countries, highlighting the impact of gender disparities on corporate and societal outcomes. The results suggest that nations with narrower gender pay gaps tend to perform better in sustainability-related metrics, underlining the interdependence of economic inclusion and sustainable development. However, data availability and methodological constraints pose certain limitations. The paper provides insights for policymakers and business leaders seeking to enhance gender equality while fostering sustainable corporate and societal practices. The originality of this research lies in its multidimensional index approach, offering a novel perspective on the intersection of gender equality and sustainability performance across diverse European economies.

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1 Introduction

The pursuit of gender pay parity has a long-standing history, dating back to the 1857 strike by approximately forty thousand textile industry workers in New York, who demanded equal wages and reduced working hours (England et al., 2020). Despite nearly 170 years of progress, gender-based wage disparities persist as a global issue. The gender pay gap (abbreviation: GPG), defined as the difference in average earnings between men and women, remains one of the most widely recognized yet contentious forms of social inequity. Extensive research has identified key contributing factors, such as unequal access to education, occupational segregation, discrimination, caregiving responsibilities, and unpaid labour, yet the gap persists significantly (Jurado de los Santos et al., 2020). While recent years have seen some progress, the pace of change toward gender parity in economic opportunities remains slow. Recognizing these challenges, the European Union (abbreviation: EU-27)'s 2020–2025 Gender Equality Strategy aims to create a society where individuals, irrespective of gender, have equal opportunities to pursue their chosen careers, attain economic prosperity, and participate in governance. However, the most recent data from 2021 reveals that, on average, women in the EU earned 12.7% less than men, with substantial variations across member states (Leythienne & Pérez-Julián, 2021).

2 Literature Review

Gender equality has been a key focus in international human rights, particularly within the United Nations (abbreviation: UN) Sustainable Development Goals (abbreviation: SDGs). The 1945 UN Charter first recognized it as a fundamental principle, and this commitment has since been integrated into international laws and policies. The Universal Declaration of Human Rights also incorporates gender equality into international human rights law (Hashmi, 2019). Gender equality is a core principle of the UN's Sustainable Development Goals, with SDG5 directly addressing it and SDG10 focusing on reducing inequalities more broadly. This reflects the recognition that achieving sustainability and social justice requires including all individuals regardless of gender (Rebelo & Guimarães, 2022). The principle of equal pay for equal work was first introduced in the Treaty of Rome and reinforced through EU-27 legislation, including the Equal Treatment Directive. This directive prohibits direct and indirect pay discrimination, requiring gender-neutral

job classification systems (Lavena & Riccucci, 2012). Wage disparities continue due to structural and cultural factors. Gender stereotypes lead to women being concentrated in lower-paying jobs and industries. Obstacles like the "sticky floor" and "glass ceiling" hinder women's career advancement and access to senior roles. Additionally, unequal caregiving responsibilities compel women to seek flexible but lower-paid work, impacting their participation in the labour market (Hsieh et al., 2023). These systemic issues contribute to wage discrimination, undermining equal pay. To address persistent inequalities, the EU-27 has launched key initiatives such as the Gender Equality Strategy and the Pay Transparency Directive. These aim to tackle pays and pension gaps, unequal representation in decision-making, and gender-based violence and stereotypes. The Directive promotes transparency through objective pay structures, salary disclosures, and reporting mechanisms (England et al., 2020). However, its implementation remains uneven across Member States, and its effectiveness is contingent upon robust enforcement and integration into broader gender equality frameworks (Boll & Lagemann, 2019). While the legal and institutional frameworks are well-established, the persistence of gender inequality in practice reveals a gap between formal commitments and lived realities. This highlights the need for a shift beyond compliance toward transformative approaches that address the structural and cultural reproduction of inequality. Gender equality and ESG are increasingly interconnected. ESG's social component aligns with gender equality goals like diverse workplaces and fair pay. Investors prioritize gender pay transparency as a key sustainability metric (Hu et al., 2023). Companies committed to gender equality drive social progress and financial performance. As the ESG framework evolves, regulatory developments such as the Pay Transparency Directive are expected to play a more central role in shaping corporate social performance metrics. Enhanced gender-related disclosures in ESG reporting frameworks are not only a matter of compliance but also reflect growing expectations for corporate accountability and inclusive governance (Zahid et al., 2023). In this context, artificial intelligence (abbreviation: AI) is increasingly employed in ESG data analysis, risk assessment, and reporting automation. AI can boost the detail and effectiveness of gender-related disclosures, but it also raises concerns about algorithmic bias, especially if the underlying data reflect existing inequalities.

3 Methodology

This paper examines the relationship between gender parity and sustainability across four European nations: Hungary, Poland, Czechia, and Spain. These countries were chosen due to their diverse economic and social development paths, varying GPGs, and differing sustainability strategies. The analysis provides a comparative assessment of how gender equality and sustainability performance intersect in these diverse environments. Particularly, the research examines the interplay between environmental performance, corporate competitiveness, and societal well-being, while accounting for the influence of gender-based wage gaps. By integrating these multifaceted dimensions, the paper endeavours to offer insights into how gender equality shapes broader economic and sustainability dynamics within diverse national settings.

3.1 Data Sources

This paper used various data sources to analyse the gender pay gap and its underlying causes. Eurostat data provided a foundation, examining the unadjusted gender pay gap - the difference in average gross hourly earnings between men and women. The Eurostat dataset covers 2010 to 2021 and includes organizations with at least ten employees, excluding agriculture. To supplement this, data from the Hungarian Central Statistical Office was incorporated, offering insights specific to Hungary. Unlike Eurostat, KSH data encompasses all economic sectors and compares the monthly gross average earnings of full-time employed men and women, providing a broader perspective on wage disparities.

3.2 Indices

The paper used various indices to analyse gender equality, including the Gender Equality Index (European Institute for Gender Equality, 2025) (abbreviation: GEI), Gender Inequality Index (Nations, 2025b) (abbreviation: GII), and Gender Development Index (Nations, 2025a) (abbreviation: GDI). The GEI, used by the EU-27, considers economic, political, and social factors influencing gender equality, tracking progress and highlighting top performers. The GII examines gender disparities in education, employment, and politics. The GDI provides insights into

gender-based differences in economic and educational opportunities across countries. These indices offer a nuanced understanding of gender-based wage inequalities within broader socioeconomic conditions.

3.3 Data Processing and Standardization

To ensure consistency and comparability, the data was carefully processed. All country-level data went through rigorous cleaning and standardization to account for differences in economic development and social factors. This involved normalizing datasets and aligning them with internationally recognized methods to maintain reliable comparisons. Trends in the gender pay gap between 2010 and 2021 were examined using data from Eurostat and KSH, as well as other relevant economic and social indicators. When analysing changes in gender pay disparities, a focus was placed on the relationship between economic performance and social policies in different countries. The paper compared the GEI, GII, and GDI indices to gain deeper insights into gender disparities and their socioeconomic implications. By examining these indices together, the research aimed to capture the complex nature of gender inequalities and their impact on wage differences. The findings not only present statistical data but also provide context through a systematic analysis of gender-based inequalities, seeking to understand the underlying causes of the gender pay gap and lay the groundwork for future policy decisions.

4 Results

The findings show an overall improvement in gender equality across the studied countries, though the pace and extent vary. Spain made the most notable progress, with its GII increasing from 0.90 to 0.94 and its GEI rising from 0.66 to 0.76. This suggests Spain has significantly reduced gender disparities and empowered women across socioeconomic areas. Poland also exhibited steady advancement, with GII improving from 0.83 to 0.89 and GEI increasing from 0.56 to 0.62, indicating a gradual yet consistent enhancement of gender equality. In contrast, Hungary showed the least improvement, with GII moving only slightly from 0.75 to 0.76 and GEI rising modestly from 0.52 to 0.57, implying slow and limited gender parity gains. The Czech Republic, starting from a higher baseline, recorded moderate gains, with GII increasing from 0.61 to 0.88 and GEI from 0.56 to 0.58, suggesting a more moderate

pace of progress in bridging the gender gap. Further analysis revealed significant variation in the degree of change. Hungary exhibited the most limited progress, with a 28.94% decline in its gender equality measure, indicating potential stagnation or regression. Conversely, the Czech Republic achieved the most substantial advancement, with a 74.31% increase in gender equality, suggesting the effectiveness of gender-focused policies and broader socioeconomic shifts. Poland and Spain recorded moderate improvements of 7.3% and 13.22%, respectively, reflecting steady but less dramatic transformations in gender equity. Based on the data, varying trends can be observed among the analysed countries between 2010 and 2021. In Hungary, the decrease in the index (from 0.2340 to 0.1663) indicates a negative change, while a significant improvement is observed in the Czech Republic (from 0.2520 to 0.4393). Both Poland and Spain exhibit an upward trend; however, the magnitude of growth is milder in Poland (from 0.5903 to 0.6334) and more pronounced in Spain (from 0.6328 to 0.7165). These differences may suggest that the impact of economic, social, or other development measures varies by country. Consequently, further analysis in regions exhibiting a declining trend is recommended to identify the underlying causes of the negative changes.

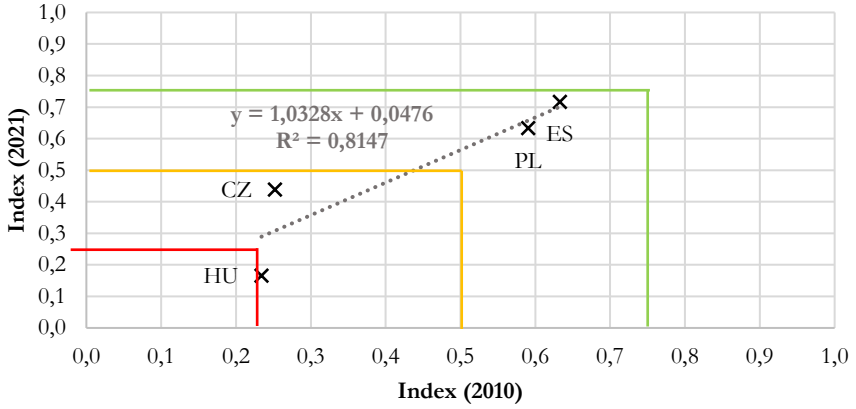

Figure 2: Comparing gender equality index values from 2010 to 2021 for the countries examined.

The analysis of the studied countries suggests three distinct patterns in their gender equality trajectories. Spain and Poland, with relatively high initial and final gender equality values, have undergone gradual but consistent improvements. In contrast, Hungary stands out as an outlier with the slowest progress, while the Czech Republic demonstrates the most significant advancement in gender equality. These varied outcomes underscore the complex interplay of policy frameworks, labor market structures, and socioeconomic conditions in shaping gender equality progress. The observed patterns highlight the multifaceted nature of gender inequality, which is influenced by policy, labor market, and broader societal factors. While the overall trajectory indicates progress, the variations across countries emphasize the need for targeted policy interventions to further bridge gender disparities and sustain advancements. The findings suggest that policy consistency, economic stability, and societal attitudes play pivotal roles in shaping the extent of gender equality progress within each national context.

5 Discussion

The results of this paper demonstrate a nuanced and at times contradictory association between gender equality indicators and the GPG. While metrics such as the GEI and GDI were expected to exhibit a negative correlation with the GPG, implying that improvements in gender equality correspond with a narrowing of the pay gap, the empirical data shows that this relationship is not consistent across all countries. Likewise, the GII was anticipated to show a positive correlation with the GPG, yet in certain instances, the findings diverge from this assumption. The analysis shows that in Spain, improvements in gender equality are strongly linked to a reduction in the GPG. However, the findings for Hungary challenge this pattern, as the gender development index had an unexpected correlation, and the gender equality index and gender inequality index exhibited weak and contradictory relationships with the GPG. The results for Czechia and Poland fall between these two extremes, with Czechia demonstrating stronger associations in certain areas, while Poland shows no clear correlation. The use of broad gender equality indices, such as the GEI, GDI, and GII, has limitations in accurately capturing specific economic inequalities like the GPG. While these indices provide valuable insights into overall gender parity, they often overlook key dimensions of labour market dynamics, economic structures, and national policy environments that shape pay

inequities (Ghosh & Ramanayake, 2021). For instance, countries with strong social protections and collective bargaining systems often achieve relatively low GPG levels despite differing gender equality profiles (Sterling et al., 2020). This paper emphasizes that while gender equality indices provide valuable insights, they alone cannot capture the nuances of the GPG. Policymakers should adopt a more comprehensive approach, accounting for labor market dynamics, social policies, and economic structures (The Nordic Gender Effect at Work, 2019). Digitalization is transforming gender data collection and analysis, with AI and algorithms increasingly used in ESG and labour market monitoring. While these technologies can enhance GPG tracking and policy evaluation, they also raise concerns about data bias and algorithmic bias, especially when trained on datasets reflecting historical inequalities. Responsible and transparent AI use is crucial to ensure digital tools support, not undermine, gender equality efforts. Closely monitoring the EU's Pay Transparency Directive is vital, as past studies suggest pay transparency can reduce wage gaps, but its success hinges on strong enforcement and broader policies.

6 Conclusions

This paper examines the complex relationship between gender equality and GPG. While indices like the GEI, GDI, and GII provide valuable insights into overall gender equality, their correlation with wage disparities varies across countries. The findings suggest that in some cases, such as Spain, these indices align with expected trends, but in others, like Hungary and Poland, the relationship is weaker or contradictory. These results indicate that broader gender equality does not always directly translate into wage parity. Factors like economic structures, labor market policies, and social norms play a significant role in shaping wage disparities, which composite indices may not fully capture. This aligns with previous research highlighting the need for more targeted measures to address gender wage inequalities beyond general equality frameworks. The paper emphasizes the importance of policy interventions, such as the EU Pay Transparency Directive, which could be a crucial step in closing the GPG. However, the directive's impact will depend on how countries implement and enforce it. Future research should track these developments and assess the directive's effectiveness in reducing wage disparities. Despite progress toward gender equality, eliminating unjustified pay differences remains challenging even in highly developed economies. A multifaceted approach,

combining policy reforms, labor market interventions, and continuous monitoring of wage data, will be essential for achieving gender pay equity.

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Quantitative Frameworks for Investigating the Relationships Between Sustainability Factors and Lifelong Learning

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In an era characterized by rapid economic growth, globalization, and pressing environmental challenges, the role of education in advancing sustainability has become paramount. This paper's primary focus is on sustainability, aiming to provide meaningful insights into the function of educational attainment, specifically lifelong learning, in promoting sustainable development. The paper's novel approach lies in its data-driven perspective, utilizing international indices to quantify the relationship between educational metrics and the UN Sustainable Development Goals. This paper adopts a quantitative, index-based methodology to compare lifelong learning performance across four countries with similar economic circumstances, utilizing sustainability indicators from the SDG Index, Youth Progress Index, and Social Progress Index. The key findings reveal that while Estonia exhibited leading performance, Hungary's index value declined between 2016 and 2022. In contrast, Turkey demonstrated the most substantial improvement during this period, despite starting from the lowest point. The paper emphasizes the importance of carefully managing educational incentives and innovations to strengthen the alignment between sustainability and lifelong learning, particularly in addressing specific sustainability challenges through targeted ESG strategies.

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1 Introduction

The dramatic changes of modern times have brought a range of economic and environmental challenges that affect society and individuals. Rapid economic growth, population increase, and globalization have increased resource use, making environmental and social impacts central topics in academia and policy (Wuaten, 2022). Concerns about sustainability have expanded beyond environmental protection, now encompassing broader social and economic aspects. In this context, education, an institution with wide societal influence and direct involvement in socioeconomic structures, must adapt and respond to these evolving challenges (Aikowe, 2021). The education system performs eight crucial functions: melding individual character, transmitting culture, upholding or altering social structures, fostering economic development, legitimizing political frameworks, promoting social cohesion, offering direct services, and either enabling or impeding societal change, while simultaneously serving as a wellspring of personal fulfilment (Sujitjorn & Lertsuksombat, 2019). The complex interplay between education, society, and the economy has only intensified over time, evolving into a global preoccupation due to expansion and globalization. Since its inception, the demand for high-calibre knowledge and expertise has been consistently rising. In modern society, this tendency has further escalated with the growing recognition of human capital as a pivotal asset for both competitiveness and sustainability. However, knowledge attainment can no longer be solely confined to acquiring essential skills for task execution (Kim & Park, 2020). The processes and settings of teaching and learning have undergone substantial transformations, with methods and tools continuously evolving. The increasing availability of information, driven by digitalization and innovative pedagogical approaches, has made learning more accessible than ever (Srivastava, 2023). Consequently, knowledge development is expanding beyond traditional schooling and formal education, emphasizing non-traditional and informal learning environments. This shift underscores the emergence of lifelong learning (abbreviation: LLL) (Jackson, 2023; Kitagawa, 2021). The growing influence of artificial intelligence is transforming learning and lifelong education, presenting both challenges and opportunities for the education system. AI integration enhances personalized experiences, accessibility, and new knowledge acquisition methods to address societal and technological changes. LLL is essential for a sustainable future. In a "knowledge-based society," individuals must continuously update their knowledge and skills to contribute to environmental preservation (Kanwar et al.,

2019). This paper examines the LLL paradigm from a sustainability-focused viewpoint. It analyses key metrics pertaining to environmental, social, and governance aspects in nations with economic circumstances analogous to Hungary's. By employing a "green lens," the research aims to provide meaningful insights into the function of LLL in promoting sustainable development.

2 Theoretical Background

The extant literature underscores that the ongoing advancement of learning not only bolsters the development of individuals and their adaptability to the workforce, but is also a pivotal factor in fostering sustainable social, economic, and environmental systems (Aikowe, 2021). The UN's 2030 Agenda accentuates the role of education in realizing the Sustainable Development Goals (abbreviation: SDGs), particularly by cultivating mindsets and skills that support sustainability (Carney & Carty, 2024). Hence, learning serves not merely as a means for personal fulfilment but can catalyse social transformation that contributes to the long-term achievement of the SDGs. The connection between LLL and sustainability is underpinned by the acknowledgment that the knowledge required for sustainable development is dynamic, continuously evolving and being renewed (Ugwuoke et al., 2021). Educating people is key to helping them adapt to sustainability challenges. It raises environmental awareness, spreads knowledge about climate change, and encourages the use of new eco-friendly technologies. The diverse modalities of LLL - formal, non-formal, and informal - can all foster education for sustainability (Aikowe, 2021). Formal education can teach sustainable development. Non-formal and informal learning can help workers and communities update their sustainability knowledge. This is crucial for the environment, social and economic sustainability. Continuous learning can reduce inequalities and improve social cohesion (Battistella et al., 2021). Research shows that LLL helps achieve wider SDGs. Education can reduce poverty by giving people skills for financial independence. It also promotes gender equality by opening up educational and job opportunities for women (Piao & Managi, 2023). Continuous learning makes the workforce more flexible and innovative, which supports sustainable economic growth and good jobs (Khan et al., 2023). LLL is crucial for promoting sustainable development. It can cultivate attitudes supportive of sustainable lifestyles and help individuals and organizations understand and address sustainability challenges (Ugwuoke et al., 2021). Through continuous skill development, LLL enables sustainability at both individual and structural levels.

3 Methodology

This paper aims to examine and compare the participation in lifelong learning activities across countries that have economic conditions similar to Hungary. By analysing the rates and patterns of lifelong learning engagement in these peer countries, the paper seeks to provide insights into the relationship between economic development and lifelong learning opportunities.

3.1 Countries Included in the analysis

The countries were selected based on a multi-pronged approach. The primary criterion was economic similarity, as measured by per capita purchasing power parity. This was necessary to ensure comparability. The categorization was based on a preliminary clustering using the Youth Progress Index, which allowed for the identification of countries with similar economic development levels. The specific countries were randomly chosen from the relevant sample. This selection considered the need to represent different geographical regions, providing an opportunity to analyse region-specific traits. Estonia, a Baltic state and EU digital education leader, Greece, representing Southern Europe, and Turkey, an emerging Eurasian economy, were included. This selection strategy ensured economic similarity while also offering insights into diverse geographical and cultural contexts, enabling an examination of varied lifelong learning participation trajectories.

3.2 Selected Indicators and Indices

Considering data availability, the years 2016 and 2022 were chosen as the reference years for analysis. The selection was influenced by two factors: methodological changes at both national and international levels were consolidated by 2016, making prior LLL-related data incomparable, and the most recent data available across all indices were from 2022. The indices selected for comparison were chosen to ensure the inclusion of key educational and social indicators. The research utilized three key international indices to assess lifelong learning participation. These included:

- The Sustainable Development Goals index (abbreviation: SDG index), which measures progress towards the UN's Sustainable Development Goals and incorporates indicators related to the quality and accessibility of education.

- The Youth Progress Index (abbreviation: YPI), which evaluates a country's capacity to provide young people with opportunities for self-actualization, including education and adult learning, based on a range of metrics.
- The Social Progress Index (abbreviation: SPI), an assessment of social progress that examines countries' provision of basic human needs, well-being, and developmental opportunities.

3.3 Standardisation and Analytical Methods

To begin, the baseline data with diverse units and dimensions is standardized into a common metric scale, following established methodologies (Macher et al., 2023; Macher & Szigeti, 2024). Next, a benchmark is defined by comparing the values of EU-27 Member States to the maximum value in the sample. This is followed by calculating the Euclidean distance, which quantifies how far the indicators are from a specific reference point. Finally, an integrated index with consistent dimensions is computed to enable a three-dimensional matrix analysis. Results should be interpreted with caution, as a small sample may not represent the broader population.

4 Results

In line with our research objectives, we conducted an index-based data analysis for the period 2016–2022 across four selected countries with similar economic conditions. Following data collection and standardization, we determined the Euclidean distance measure and the adaptive development index for ecosystem services. The average index value for the analysed countries was 75.75 in 2016, increasing to 77.36 in 2022 (Figure 1.) The results indicate that in 2016, Turkey had the lowest index value (0.1636), followed by Greece (0.8100). Estonia led in lifelong learning participation. By 2022, Hungary's performance declined to an index value of 0.7400, reflecting a -5.89% decrease. Turkey remained the lowest-ranking country but showed the most significant improvement (+21.57%) from 2016 levels. Greece exhibited a slight decrease (-0.9%), indicating stagnation.

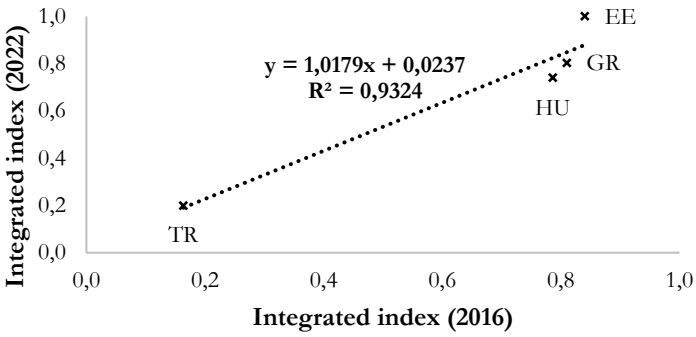

Figure 1: Comparative analysis of calculated integral indices

Comparing our findings with EUROSTAT data, we observe that Estonia is the only country that surpassed its pre-pandemic (2019) performance. The results suggest that the examined countries can be categorized into two groups, with Estonia significantly outperforming the other three in lifelong learning engagement (Figure 2.).

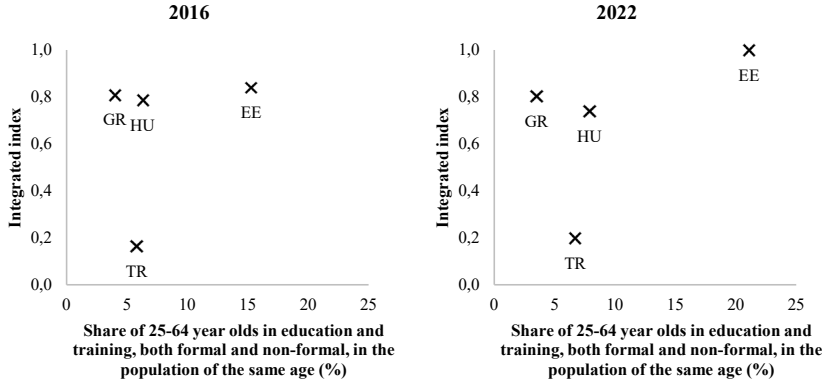

Figure 2: Comparative analysis of LLL and standardised indices

5 Discussion

This research aligns with prior work examining the relationship between sustainability and lifelong learning, building upon existing frameworks through a novel index-based methodology. Previous studies have underscored education's role

in cultivating sustainability by shaping attitudes and conduct (Michel, 2020). The current findings expand upon this foundation by incorporating quantitative metrics to evaluate the impact of lifelong learning on sustainable development. Prior research has often focused on the qualitative aspects of sustainability education, such as curriculum development and instructional approaches. In contrast, this paper leverages international indices to offer a more data-driven perspective, illuminating the relationships between educational metrics and sustainability goals (Peters et al., 2024). For instance, work by organizations like UNESCO has emphasized the need for a comprehensive approach to sustainability education, which this analysis complements by providing empirical insights derived from index-based assessment (Redman & Wiek, 2021). This paper offers a novel methodological approach that departs from conventional research focused primarily on policy implications. This interdisciplinary framework can be applied across diverse educational settings. Importantly, our research underscores how lifelong learning shapes sustainable practices at both the individual and societal levels. The findings corroborate the argument regarding the need to align educational initiatives with the United Nations' SDGs (Filho et al., 2023). By analysing SDG-related indicators, our paper offers additional empirical support for the notion that tailored educational strategies can foster sustainable outcomes (Filho et al., 2023). While prior research has primarily examined the role of higher education in sustainability, this work expands this focus to encompass lifelong learning, including adult education and continuous professional development.

6 Conclusions

This investigation has elucidated the pivotal nexus between sustainability and lifelong learning, underscoring how education can function as a catalyst driving sustainable development. By adopting an index-based methodology, we have furnished empirical evidence that lifelong learning occupies a fundamental role in cultivating sustainable practices, exerting influence on both individuals and societal frameworks. The results of this paper highlight the imperative of embedding sustainability principles within lifelong learning frameworks, ensuring that educational initiatives at all levels advance global sustainability objectives. Moreover, the findings demonstrate that interdisciplinary methodologies, particularly those leveraging quantitative data, can generate valuable insights into the relationship between education and sustainability. Although our research offers valuable insights,

it also has certain limitations, such as the scope of the indices employed and the geographical constraints of the data. To build upon these findings, future studies should incorporate a wider range of datasets and delve deeper into regional disparities. Furthermore, additional investigations into the direct impact of policy implementation on sustainability outcomes would provide valuable insights. Ultimately, lifelong learning must be continually supported and advanced to address the challenges of sustainability. By cultivating knowledge acquisition, skill improvement, and behavioural modification, education can serve as a driving force in realizing sustainable development, not merely as an end goal, but as a fundamental component of a more sustainable future.

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Impact of AI in Human Resource Management (HRM), Focusing on Recruitment and Selection

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Integrating Artificial Intelligence (AI) in Human Resource Management (HRM) has transformed traditional HR practices, enhancing efficiency and decision-making through data-driven insights. This study investigates the impact of AI on HRM practices, specifically focusing on its influence on recruitment processes and the barriers faced by job seekers in this evolving landscape. A structured questionnaire was distributed to HR professionals and job seekers across various industries. The questionnaire aimed to assess perceptions of AI's effectiveness in recruitment, its role in decision-making, and the obstacles job seekers encounter when interacting with AI-driven systems. Preliminary results indicate that AI significantly enhances recruitment efficiency by automating candidate sourcing and screening. But it also introduces significant barriers for job seekers, including algorithmic bias, and the impersonal nature of AI interactions. However, challenges such as data privacy concerns and resistance to change were identified. The study concludes that while AI has the potential to revolutionize HRM practices, ethical implications, and accessibility issues must be addressed to create a more inclusive recruitment environment. This research contributes to the growing body of literature on AI in HRM and highlights the importance of balancing technological advancement with equitable recruitment practices.

Keywords:
artificial intelligence, human resource management, recruitment, selection, challenges employee engagement,

JEL:
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1 Introduction

The rapid advancement of Artificial Intelligence (AI) has transformed various sectors, notably Human Resource Management (HRM). This study investigates the impact of AI on HRM practices, specifically focusing on its influence on recruitment processes and the barriers faced by job seekers in this evolving landscape. There is a strong indication that the future of HRM practices will be marked by extensive digitalization and increased virtualization, driven by AI technologies. This shift aims to achieve a sustainable competitive advantage through enhanced human capital and HRM practices that align with Industry 4.0 standards. Allowing It emphasizes smart factories and the digitization of production and business operations, allowing for greater efficiency, flexibility, and customization.

If we seek to identify all AI techniques currently aiding business functions, an important question emerges: are they genuinely applicable to different HRM functions?

This suggests that there is still substantial work to be done, requiring future researchers to systematically identify and evaluate the relevance of AI techniques for specific HRM tasks. Additionally, the systematic literature review (SLR) reveals a research gap concerning the outcomes of AI in HRM. Previous studies have largely overlooked the analysis of how AI-driven HRM outcomes connect to broader organizational results.

2 Theoretical Background /Literature Review

Many researchers agree that AI can significantly benefit organizations. When applied to the recruitment process, AI helps manage large volumes of applicants by streamlining tasks such as resume screening, ensuring a faster and more efficient evaluation process FraiJ&László (2021). The practical application and benefits of AI in recruitment present a paradox. While there is broad consensus about its potential, challenges arise in its use. For instance, if AI relies on human decision-making patterns derived from the data it analyses, it may replicate past decisions based on established trends in recruitment and selection. This highlights the importance of considering human judgment when utilizing AI-driven recruitment tools, as they may reinforce existing biases or patterns (Dessler, 2020). Similarly, if we aim to

capture all the AI techniques currently supporting business functions, a key question arises: are they truly applicable to various HRM functions? This indicates that much work remains to be done, with future researchers needing to systematically identify AI techniques and assess their suitability for specific HRM functions. Furthermore, the systematic literature review (SLR) highlights a gap in research on the outcomes associated with the use of AI in HRM. There is a significant void in previous studies regarding the analysis of how HRM outcomes, driven by AI implementation, relate to broader organizational outcomes. Columbus (2018) found that HR departments leveraging AI-driven analytics were able to forecast staffing needs by analysing historical data, market trends, and employee performance metrics.

Expert System Theory in Recruitment applies the principles of expert systems to automate and enhance the decision-making process in recruitment and talent management Walley (1996). Expert systems theories are used to explore the diffusion of AI has been used from Golec & Kahya, (2007) in performance management and recruitment and selection embraced the theory of constructing hierarchies for competency-based evaluation and selection of job applicants in the recruitment and selection process Daramola, Oladipupo & Musa, (2010).

The Technology Acceptance Model (TAM) explains how users come to accept and use new technologies. It focuses on two main factors: perceived ease of use and perceived usefulness. Application in HRM: TAM can be applied to understand how HR professionals and employees perceive AI tools in HR processes such as recruitment, performance management, and learning & development. If users believe AI tools are easy to use and helpful in improving HRM outcomes, they are more likely to accept and integrate them into their practice Binns (2018).

3 Methodology

A structured questionnaire was developed to explore multiple dimensions of Artificial Intelligence (AI) in Human Resource Management (HRM), specifically focusing on the areas of recruitment and selection. The questionnaire was designed to capture insights on several key aspects, including perception, usability, effectiveness, and the challenges associated with the use of AI technologies in HRM practices. By addressing these diverse factors, the survey aimed to provide a comprehensive understanding of how HR professionals view AI tools and their

impact on the recruitment and selection process. The questions formulated for this research were crafted by synthesizing recent studies on the intersection of artificial intelligence (AI) and human resource management (HRM). This involved a comprehensive analysis of various AI applications currently employed in the recruitment and selection processes. Additionally, the research incorporated an examination of relevant theoretical frameworks, including expert system theory and the technology acceptance model, to better understand the implications and effectiveness of these AI tools in HR practices. By integrating these diverse sources of information, the research aims to provide a nuanced perspective on the role of AI in enhancing HRM strategies.

To ensure clarity and precision, the survey was composed primarily of objective questions, which enabled respondents to provide specific, measurable responses. These objective questions were crafted to gather in-depth insights into the application, challenges, and effectiveness of AI in the recruitment and selection process. By using structured questions, the survey aimed to minimize ambiguity and allow for comparability across responses. The questionnaire was distributed online to HR staff. The data collected was subsequently analyzed but only in the descriptive analysis, allowing for the identification of insights that reflect the general attitudes and experiences of HR professionals with AI technologies.

4 Results

The survey was distributed to HR professionals from a broad range of industries, ensuring a diverse and representative sample of respondents. It was also distributed to managers and executive directors in smaller firms that do not have HRM departments, considering that they are responsible for hiring decisions. Trying to facilitate a robust response rate, was essential for ensuring the validity and reliability of the findings. From the distributed questionnaires we had 81 responses, in the following figure we can see the variety of the sectors that we had and we had 74 responses from the specific sectors and 7 from other fields that were not identified. The percentage of the responses is highest in the private sector with 33.8% and lowest in consulting and NGOs with 6% to 8 %.

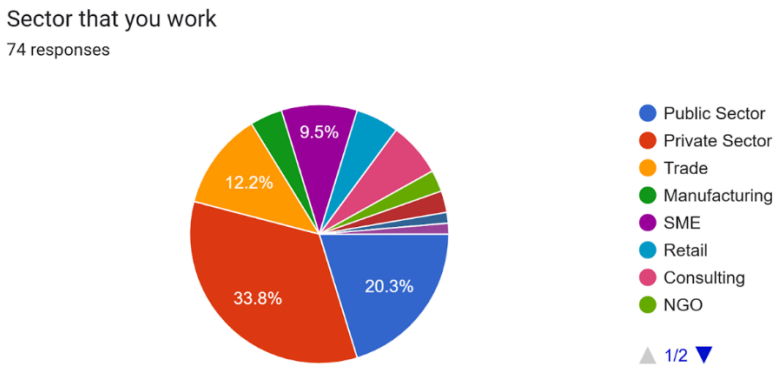

Figure 1: Responses on the sectors of respondents

The study highlights the need for strategic implementation of AI tools in HRM, ensuring ethical considerations and employee buy-in. The findings contribute to the understanding of AI's evolving role in HRM and provide actionable insights for organizations seeking to leverage technology in their HR practices. In the question regarding do they believe that AI has a significant role in transforming HR practices as recruitment and selection 19.8% strongly agree. 66.7% agree, 11.1% are neutral and 3.17 disagree. In the questions regarding how familiar are they with the use of AI in recruitment and selection 22.2% responded that are very familiar 64.2 % responded that they were somewhat familiar and 13.6% responded that they were not familiar at all.

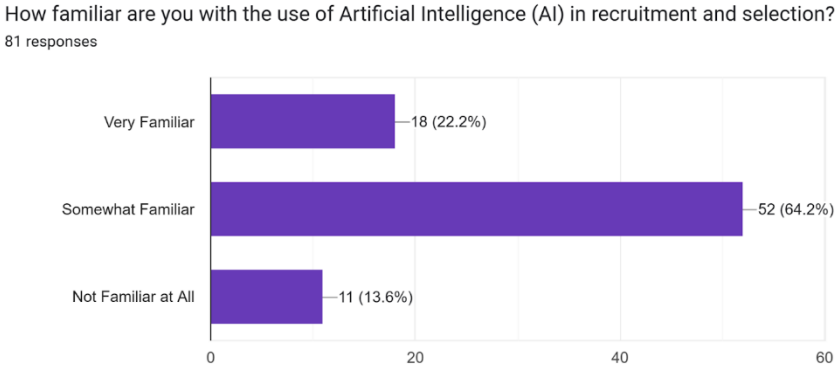

Figure 2: Familiarity of AI in R&S

In Figure 3 below we see that chatbots for screening are the most used with 51.9%in our research AI-driven chatbots being used to engage with candidates, answer questions, schedule interviews, and provide real-time updates. They improve the candidate experience and make the recruitment process more efficient. Research by Tambe, Cappelli & Yakubovich (2019) highlight how AI-based algorithms help to filter candidates based on relevant skills and experience, significantly speeding up the hiring process. From our responses Video Interviewing platforms are also used in the recruitment process with 34.6 % of the respondents using it, followed by applicant tracking systems with 33.3% usage and almost 15 % of not using it at all in their organizations.

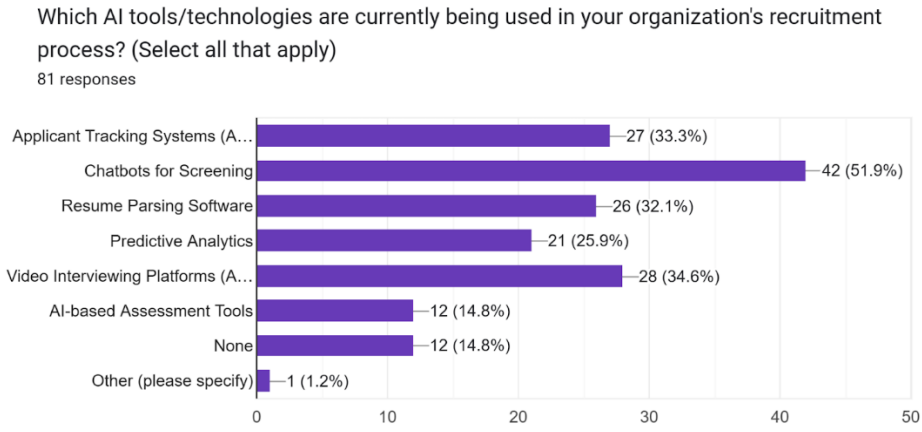

Figure 3: Usage of AI in R&S by HRM

There are several barriers that HRM and their professionals face when implementing these technologies. These obstacles include concerns of Over-reliance on technology with the responses of almost 50% in our research, lack of human touch 43 % of respondents, data privacy responses of around 37.5 %, ethical considerations, and limited understanding and difficulty in interpretation also an issue therefore the adaption on AI tools.

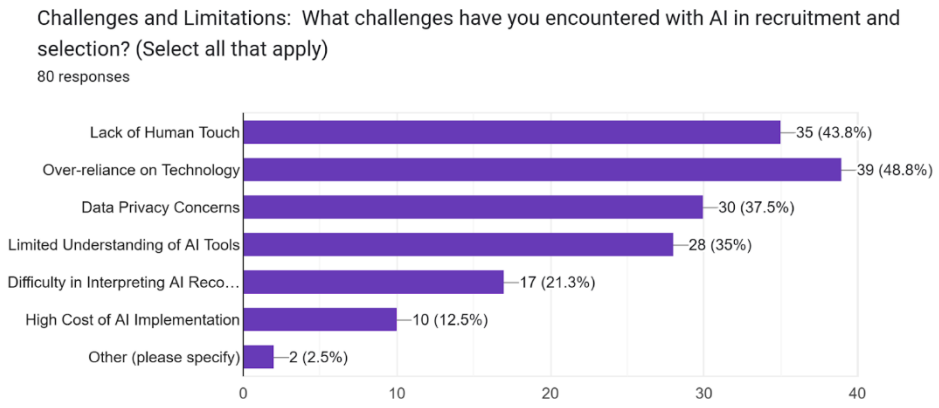

Figure 4: Challenges and Limitations in using AI in HRM

5 Discussion & Conclusions

This research provided valuable insights into the adoption and integration of AI in Human Resource Management (HRM), offering a comprehensive understanding of its impact on recruitment and selection processes. It highlighted not only the numerous benefits that AI brings to HR practices, such as increased efficiency, reduced bias, and enhanced decision-making but also the barriers and limitations that are faced by organizations.

Results from this research indicate that AI significantly enhances recruitment efficiency by automating candidate sourcing and screening, while also improving employee engagement through personalized communication and feedback mechanisms. However, challenges such as data privacy concerns and resistance to change were identified.

The findings contribute to the understanding of AI's evolving role in HRM and provide actionable insights for organizations seeking to leverage technology in their HR practices. Through this research, valuable insights were gathered regarding the adoption and integration of AI in HRM, highlighting both the benefits and the barriers faced by HR professionals. These insights are crucial for understanding how AI is shaping the future of recruitment and selection and what improvements or adjustments might be needed to maximize its potential in HR practices. Key findings

indicate that while AI enhances efficiency and candidate screening accuracy, it also introduces significant barriers for job seekers, including algorithmic bias, lack of transparency in AI decision-making, and the impersonal nature of AI interactions. The study concludes that while AI has the potential to revolutionize HRM practices, there is an urgent need to address the ethical implications and accessibility issues to create a more inclusive recruitment environment. Recommendations for HR practitioners are provided to ensure that AI tools are implemented in a manner that supports rather than hinders job seekers. The benefits of AI in recruitment among others are higher efficiency, reduced bias, better candidate experience, and more accurate data analytics. The discussion surrounding the role of human emotions in the recruitment process highlights the potential drawbacks of relying solely on AI software. While AI can undoubtedly enhance efficiency and minimize human error, an over-reliance on technology may lead to a depersonalized recruitment experience, resulting in diminished empathy and understanding between candidates and recruiters.

Incorporating human emotions into decision-making is crucial, as it fosters meaningful connections that can significantly influence a candidate's experience and perception of the organization. Future research should focus on finding the right balance between harnessing the strengths of AI and acknowledging the irreplaceable value of human interaction in recruitment. It is essential to explore how to integrate AI in a manner that complements, rather than replaces, the human element in recruitment processes.

Limitations of the study; The study is subject to several limitations, primarily due to the small number of respondents and the limited number of organizations currently employing AI throughout the recruitment process. This may affect the findings and depth of the insights that can be drown of this research. To enhance the robustness of future research, it would be beneficial to include a larger and more varied sample of respondents and organizations. This would provide a more comprehensive understanding of the impact of AI on recruitment processes and allow for richer insights that could inform best practices in the field.

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Leveraging AI-Driven Supply Chain Analytics for Accelerating the Circular Economy: A Focus on Real-Time Resource Management and Extended Product Life-Cycles

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Digital supply chains are increasingly critical to advancing circular-economy models because they couple artificial intelligence (AI), the Internet of Things (IoT) and big-data analytics to provide real-time resource tracking, predictive maintenance and data-driven end-of-life product management. **Purpose –** This article investigates how such AI-enabled analytics accelerate the shift from linear to circular supply chains. **Design/methodology/approach –** A systematic literature review followed by a Summative Content Analysis (SCA) was conducted on eight Web of Science-indexed articles published between December 2024 and March 2025. **Findings –** The evidence shows that integrating AI-based analytics strengthens supply-chain resilience, cuts resource inefficiencies and supports closed-loop flows, provided that organisational capabilities and policy frameworks are in place. **Research implications –** The study consolidates emerging knowledge on the enablers and barriers of AI-driven circular supply chains and proposes future research avenues. **Practical implications –** Managers can leverage real-time analytics to extend product life-cycles and minimise waste. **Originality/value –** This is one of the first reviews to apply SCA to recent empirical work at the intersection of AI, supply-chain analytics and the circular economy.

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1 Introduction

The integration of artificial intelligence (AI) and blockchain in the supply chain, besides contributing to the economic growth of countries («The Visegrad Group and the Industry 4.0», 2020) also enhances its sustainability by improving efficiency, minimizing waste, and ensuring ethical sourcing (Dagou & Gurgun, 2024; Onyeaka et al., 2023; Pap et al., 2025). While blockchain boosts traceability and accountability (Dagou & Gurgun, 2024), AI optimizes resource use and promotes circular economy practices, i.e., reusing, repairing, and recycling materials (Hasan et al., 2023; Liu et al., 2023; Onyeaka et al., 2023). However, not all organizations are ready to implement AI promptly in the face of SC uncertainties (Chowdhury et al., 2025; Rashid et al., 2025), so they must develop capabilities to assess AI's impact on sustainable SC performance, fostering innovative environmental solutions and boosting efficiency and resilience (Barhmi et al., 2024; Chowdhury et al., 2025). This shift requires adopting a circular economy model, which contrasts with the traditional linear "take, make, dispose" approach by prioritizing waste reduction and resource efficiency (Amoah et al., 2022).

This paper hypothesises that AI-driven digital supply chains, real-time tracking and proactive maintenance reduce waste and environmental impact. **The remainder of the paper is structured as follows:** Section 2 reviews the theoretical foundations of supply-chain management and the circular economy; Section 3 details the Summative Content Analysis methodology; Section 4 presents the results; Section 5 discusses practical and theoretical implications; and Section 6 concludes the study and outlines recommendations for future research.

2 Theoretical background

Supply chain

SC covers the process from raw material supply to product distribution, including production, processing, transportation, and distribution (Sutar et al., 2024). Due to the interconnectivity of product components, SCs can quickly become complex and fragile (Hasan et al., 2023), a complexity that underlines the relevance of Industry 4.0 technologies, or "smart manufacturing," including AI, IoT, and big data analytics, which boost efficiency, flexibility, and agility while mitigating business risks

(Rashid et al., 2025). AI, in particular, strengthens SC's adaptability and resilience to dynamic customer demands (Barhmi et al., 2024; Kusiak, 2023).

Also, servitization is increasingly integrated with Industry 4.0, fostering digital transformation that improves efficiency and competitiveness (Chowdhury et al., 2025). These technologies enable autonomous SCs capable of predictive analytics for improved decision-making, where IoT supports real-time monitoring and cost reduction in SC management (Kusiak, 2023).

These theoretical views highlight the strategic role of Industry 4.0 in SC management. Thus, the resource-based view emphasizes disruption mitigation and profitability (Javed et al., 2024), while dynamic capability theory emphasizes flexibility in adopting new technologies. Moreover, digital SCs encourage circular economy practices, supporting UN sustainable development goals, whereas business-to-business and industrial chain theories provide frameworks for resilience strategies in disruptive scenarios (Sutar et al., 2024).

Circular economy

Circular economy (CE) is essential for sustainable SC management (SSCM), promoting reuse, recycling, and remanufacturing to facilitate smarter use and manufacture of products (Liu et al., 2023). Circular SCs follow a five-stage life cycle: design, production, delivery, operation, and end-of-life (Acerbi et al., 2022). Faramarzi-Oghani et al. (2022) highlight key sustainability indicators and performance optimization methods. However, emerging technologies and resource scarcity, intensified by the COVID-19 pandemic, present both challenges and opportunities for SSCM (Sarkis, 2022).

Some benefits of CE include economic growth, supported by EU strategies benefiting society, industry, and the environment (Onyeaka et al., 2023), as well as business and employment opportunities, particularly in industries like plastics (Kahlert et al., 2022), while reducing resource exploitation and pollution, promoting sustainable growth (Ahmed et al., 2022).

Moreover, Industry 4.0 technologies–AI and big data analytics–boost efficiency and risk mitigation in SC operations (Rashid et al., 2025). Digitalizing SCs also reinforces CE practices, aligning with the UN Sustainable Development Goals (Sutar et al., 2024), where AI facilitates data collection for sustainability, mostly in manufacturing.

3 Methodology

Summative Content Analysis (SCA) was applied to eight open-access Web of Science-indexed articles (December 2024 - March 2025) identified using "Artificial Intelligence," "Supply Chain," and "Circular Economy," arranged from newest to oldest. SCA systematically merges quantitative content analysis with interpretive qualitative insights, providing a robust framework for examining textual data.
The papers included are:

1. Industry 4.0 Technologies (Procedia Computer Science) (Kopeinig et al., 2024).
2. Digital learning, big data analytics, and mechanisms for stabilizing and improving supply chain performance (Barhmi et al., 2024).
3. The role of advanced technologies and supply chain collaboration: during COVID-19 on sustainable supply chain performance (Javed et al., 2025).
4. Smart product platforming powered by AI and generative AI: Personalization for the circular economy (Akhtar et al., 2024).
5. Utilizing intelligent technologies in construction and demolition waste management: From a systematic review to an implementation framework (Wu et al., 2024).
6. Accelerate demand forecasting by hybridizing CatBoost with the dingo optimization algorithm to support the supply chain conceptual framework precisely (Abed, 2024).
7. The future of green skills for the manufacturing sector (Lagorio et al., 2024).
8. Integrating Industry 4.0 for enhanced sustainability: Pathways and prospects (Khan et al., 2025).

SCA starts by tallying specific words or content to identify patterns (Hsieh & Shannon, 2005) and then goes beyond mere frequencies to explore deeper contextual or latent meanings (Krippendorff, 2013). Researchers first select and quantify relevant terms, generating a basic overview; they then investigate how and why these terms are used to reveal interpretive layers not evident from counts alone (Hsieh & Shannon, 2005). By examining both manifest and latent content, SCA uncovers broader cultural, social, or psychological influences on language choices (Elo & Kyngäs, 2008).

4 Results

All eight articles spotlight Industry 4.0 and AI/machine learning, emphasizing data-driven decision-making, advanced manufacturing, and predictive analytics for SC optimization. Big data analytics appear in seven, while #7 referenced "data analysis skills" more indirectly; IoT likewise features in seven (#4 centered on generative AI). Five pieces (#1, #2, #3, #7, #8) discuss digital SCs, linking transformation to operational or sustainability benefits. Six (#1, #3, #4, #5, #7, #8) highlight CE concepts (resource recovery, waste reduction, end-of-life strategies), three address predictive maintenance (#1, #2, #8), and another three end-of-life management (#4, #5, #8). Organizational frameworks and barriers, including policy, training, and readiness, are explored in six (#1, #3, #5, #7, #8, and #2 to some extent).

Digital SC and CE often overlap—particularly in #1, #3, #5, and #8—where real-time data supports resource efficiency and closed-loop operations. AI/Industry 4.0 is near-universal, ranging from algorithmic breakthroughs (#2, #6) to connectivity-driven frameworks (#1, #8). Predictive maintenance (#1, #2, #8) is consistently linked to reduced downtime and waste, while end-of-life management (#4, #5, #8) involves digitally tracking products to facilitate reuse and recycling. All studies note efficiency gains (e.g., lower inventory, energy savings) and environmental benefits, with policy, governance, and skills (in #1, #2, #3, #5, #7, #8) as critical enablers, stressing cross-sector collaboration and regulatory alignment for full digital-circular implementation.

5 Discussion

AI-driven SC analytics can significantly advance CE practices by integrating AI, IoT, and big data analytics for real-time resource tracking, predictive maintenance, and optimized end-of-life product management (Liu et al., 2023; Onyeaka et al., 2023). Predictive analytics and automated resource allocation further boost decision-making in SCs, helping firms anticipate disruptions, minimize surplus inventory, and align with CE principles (Hasan et al., 2023). AI-driven transparency also strengthens sustainability compliance and stakeholder confidence (Dagou & Gurgun, 2024).

However, challenges persist. Many organizations, especially SMEs, lack the expertise and resources to incorporate AI into current SC systems (Chowdhury et al., 2025), and data security and ethical concerns remain pressing (Dagou & Gurgun, 2024). Policy support is vital for guiding environmentally and socially responsible AI integration (Rashid et al., 2025). Collaboration among industry, policymakers, and tech providers is needed to overcome these obstacles and accelerate AI-based CE models.

6 Conclusions

The eight studies highlight key barriers—limited public awareness, technological support, and policy frameworks—and confirm the importance of AI, digital SCs, predictive maintenance, and end-of-life management. All eight report that AI and Industry 4.0 enhance sustainability, six explicitly promote CE strategies, three examine predictive maintenance, and three focus on end-of-life recovery. This supports the hypothesis that AI-driven, real-time trackin,g and proactive maintenance reduce waste and environmental impact, provided organizations align these tools with supportive policies and skill-development measures.

The study's originality lies in its empirical focus on AI's contribution to circular SCs, thus adding to sustainable SC literature. However, reliance on secondary data and potential bias in content analysis are noted limitations. Future research should include empirical case studies and longitudinal approaches to better assess AI's long-term effects on circular SCs.

Finally, AI-driven analytics offers a promising route to achieving sustainability goals. By addressing existing obstacles and fostering cross-sector collaboration, businesses can leverage AI to create resource-efficient, resilient, and circular SC ecosystems.

Overall, this study set out to determine whether – and in what ways – AI-enabled supply-chain analytics support circular-economy objectives through real-time transparency and predictive maintenance. By synthesising insights from eight recent empirical studies, it contributes a focused understanding of how data-centric decision-making, powered by Industry 4.0 technologies, can shrink material footprints and extend product life-cycles. Future research should validate these mechanisms in longitudinal, multi-tier case studies across diverse industries; quantify the social-economic trade-offs of large-scale AI adoption; and explore governance models that protect data privacy while encouraging cross-industry collaboration.

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Criteria to Support the Transition Towards Circular Supply Chains – Integrating Legal, Practical and Academic Perspectives

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Circular Economy (CE) has emerged as a trend in both practical and academic discourse and has recently been adopted into core EU sustainability legislation such as the Eco-Design Directive. Redesigning supply chains to incorporate principles of circularity bears the potential to enhance sustainability performance. However, to date, holistic, inclusive, and versatile frameworks that support this redesign are missing. Based on this, the present paper introduces such a framework and discusses the current state and comprehensiveness of its included metrics. An analysis of documents stemming from academic, practical and legal discourses was conducted in order to identify CE criteria and indicators, and consequently, these were synthesised in an integrated framework. The framework contains 29 categories, 73 criteria and 408 potential indicators assigned to the four dimensions: "Environmental", "Economic", "Social" and "Governance". The integration of the different discourses enabled the development of a comprehensive set covering a wide range of metrics. Still, some important content gaps and methodological limitations have been identified that should be rectified to further refine the framework.

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1 Introduction

In today's interconnected economy, companies across various sectors participate in global supply and value chains (GSVCs). This poses different sustainability challenges and therefore, various stakeholder groups as well as core legislative frameworks of the EU Green Deal increasingly demand the reporting, monitoring and enhancement of the sustainability performance in GSVCs. Related to this, the circular economy (CE) has been introduced as a normative framework in both practical and academic sustainability discourse. CE-related aspects have also been recently adopted into core EU sustainability legislation, such as the Eco-Design Directive or the Corporate Sustainability Reporting Directive (CSRD). Therefore, companies nowadays are increasingly challenged to enhance both the overall sustainability performance of GSVCs as well as integrating CE-related principles into their operations.

While redesigning supply chains to incorporate principles of circularity bears the potential to enhance sustainability performance (Agyabeng-Mensah et al., 2023), the pursuit of such transformation mandates a deeper understanding of the environmental, social and economic aspects and measures decision-makers need to consider and prioritise in global supply chain management. The importance of key performance indicators (KPIs) and measurement frameworks to assess and enhance sustainability performance in supply chain management has been widely acknowledged (Panigrahi et al., 2019). However, existing assessment frameworks often exhibit critical shortfalls, such as inadequate adaptability to specific industry needs (Toubolic & Walker, 2015) or a lack of consideration of particular sustainability dimensions (Negri et al., 2021). Also, assessment frameworks for general sustainability performance and circularity performance seem so far to be somewhat disconnected (Allen et al., 2021) as sustainability frameworks fail to integrate circularity metrics comprehensively. These gaps highlight the pressing need to develop more holistic, inclusive, and versatile frameworks that support the transition to circular supply chains.

This paper aims to contribute to fulfilling this need. It presents an integrated framework, developed by identifying and synthesising currently discussed CE criteria and indicators in both academic literature as well as documents stemming from the practical and legal realm, and discusses the current state and

comprehensiveness of included metrics. The framework can serve as a basis for industry-specific performance measurement sets and further development of strategies for circular supply chain (CSC) management. The rest of the paper is structured in the following way: First, the core concepts of CE and CSCs, which serve as a background for the research, are discussed (Ch. 2). Then, the methodology (Ch. 3) and the results of the study (Ch. 4) are presented, before the paper ends with a discussion (Ch. 5) and conclusion (Ch. 6).

2 Core concepts: circular economy and circular supply chains

There are different approaches to conceptualising the CE, but most definitions focus on the minimisation of waste and resource use by circulating products and materials within the economy for as long as possible. In accordance with this, Kirchherr et al. (2017, p. 229) define CE as "… an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes." Furthermore, CE operates at the micro, meso and macro level and is enabled by novel business models and responsible consumers (Bressanelli et al., 2019). The so-called '10R-imperatives' prescribe a hierarchical order of strategies for the transition towards a CE (see Figure 1). According to this concept, strategies that aim towards a reduction of resource use and waste generation right from the beginning of a product's lifecycle should be prioritised. Therefore, the highest priority is given to those strategies that lead towards a minimum use of resources by either refusing unnecessary products, intensifying product use or reducing the material intensity of production. In the next step, strategies such as reuse, repair, refurbishment or remanufacturing should be applied to prolong the use of a product or its components before the return of materials through recycling or recovery is considered.

The transition towards a CE has been framed as one of the main strategies for achieving sustainable development (e.g., Murray et al., 2017). In CE literature, supply chains are seen as a key enabler of the CE transition (Lahane et al., 2020). CSCs aim to close, slow and narrow resource loops in their direct or broader realm of activities (Farooque et al., 2019). However, while existing literature mostly provides knowledge on the implementation of CE practices from a micro-perspective (e.g., the company-level) (Ünal et al., 2019), as well as on the barriers and enabling factors from a macro-perspective (e.g., on a policy-level) (Urbinati et al., 2021), the adoption

of CE principles at the level of supply chains is still a poorly explored management topic. A key question in this regard is how supply chain managers can evaluate circular performance and create internal incentives that support the shift towards CSCs (Ellen MacArthur Foundation, 2024). Notably, the development of robust and standardised KPIs for CSCs is still in its infancy. In a literature review of CE indicators for supply chains, Calzolari et al. (2022) indicate a lack of consensus on which metrics and methods best capture circular performance, signalling a need for research into adaptable, industry-specific KPIs that can reliably drive circular practices. With CE indicators for supply chains stemming from different academic threads, the literature on CSC indicators is still very fragmented. In addition, Morseletto (2020) points towards the necessity of investigating not only existing but also possible or advisable CE targets which have not yet been applied in practice. Arguably, new targets are needed because existing ones only generally cover limited arrays of CE solutions, such as recycling or efficiency improvement.

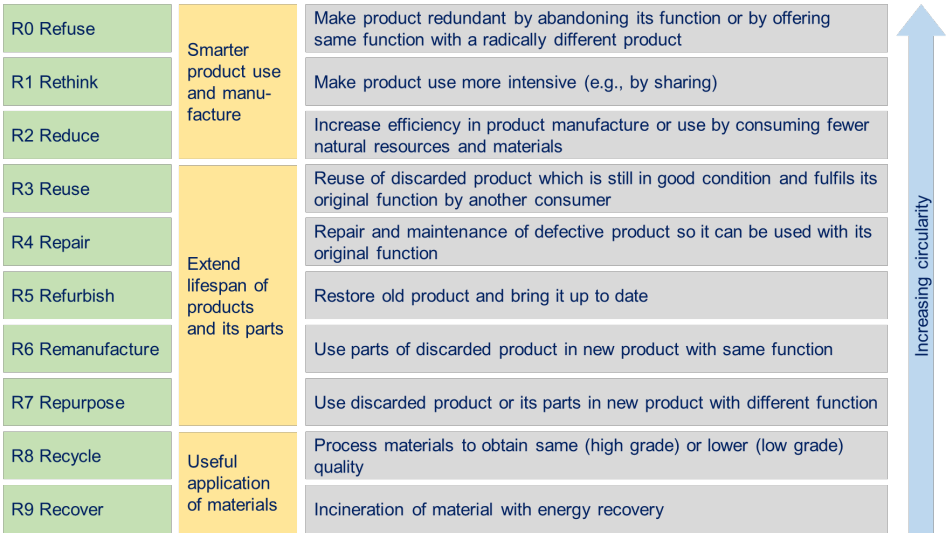

Figure 1: 10R-Strategies (Kirchherr et al., 2017)

3 Methodology

The framework development comprised a three-step procedure: First, a collection of relevant documents from the political, practical and academic CE discourse serving as a basis for the extraction of criteria and indicators took place. The final

selection included four legal regulations, two practical and six currently published academic frameworks. Second, these documents were analysed with regard to the included criteria and indicators and the information identified was listed. Third, the listed aspects were synthesised in an integrated framework covering four different levels: dimensions, categories, criteria and indicators. While dimensions represent overarching fields of topics in the area of sustainability, categories designate individual subject areas contained in these dimensions. Based on widely used concepts such as the Triple-Bottom-Line and the ESG principles, the four dimensions "Environmental", "Economic", "Social" and "Governance" have been incorporated into the framework. Criteria show targets within the individual categories that are aimed at improving sustainability, and indicators represent information that can be used for their measurement. After the framework development, additional analyses were conducted in order to assess the current state and comprehensiveness of included metrics: The numbers of categories, criteria and indicators were determined and evaluated on an overall and dimension-specific level. Beyond that, the CE specificity of each indicator, as well as its affiliation to the R-strategies, was assessed and the assessment results analysed descriptively.

4 Results

The integrated framework developed in this study contains 29 categories, 73 criteria and 408 potential indicators assigned to the four dimensions "Environmental", "Economic", "Social" and "Governance". Table 1 presents the concrete numbers of categories, criteria and potential indicators assigned to each dimension. The *environmental dimension* deals with topics such as material resources, waste, water, and energy, as well as products and services offered. It comprises criteria, for example, as reduced waste generation and use of material resources, as well as an environmentally friendly and circular product design. The material intensity represents an exemplary indicator identified in this dimension. The categories within the *economic dimension* are addressing classic economically relevant topics such as costs, revenues and efficiency. The associated criteria cover goals such as a reduction of costs and risks, an increase of revenues and the efficient use of supply chain assets. A potential indicator is the revenue generated from upgrade, repair and maintenance services of products. The *governance dimension* covers topics such as sustainable management, strategy and planning as well as external engagement. It comprises criteria, for example, as an alignment of the company strategy to CE and an

engagement with policymakers to support the transition to a CE. The latter can be measured, for instance, by the existence of verifiable engagement formats. Finally, the *social dimension* comprises the subject areas of health and safety, people and skills, as well as a contribution to the local economy. The criteria assigned to these include aspects such as the provision of decent work, training and other benefits for employees or the safe and reliable product use for customers. An example of the identified indicators is the number of fixed and variable jobs created by the CSC. A summary of the framework can be found in the Appendix.

Table 1: Number of categories, criteria and potential indicators included in framework (own analysis)

Dimension	Categories	Criteria	Potential indicators
Environmental	10	30	228
Economic	11	16	89
Governance	5	18	49
Social	3	9	42

Measured against the numbers presented in Table 1, it can be seen that the CE discourse, when viewed holistically, to date has focused especially on environmental aspects, while social factors have received the least attention. Furthermore, economic and governance aspects seem to be taken into account, however, to a lesser extent than environmental ones. Besides that, when comparing the academic, practical and legal discourse, it is noticeable that the scientific literature has produced the most comprehensive frameworks to date, followed by the practical approaches and finally the legal regulations. While all three strands cover the environmental dimension, albeit to varying degrees, the economic and social dimensions in particular appear to have received little consideration in the practical and legal frameworks. In addition, gover-nance aspects appear to have been addressed relatively comprehensively only in the practical discourse. Finally, only a small number of criteria have been taken up in all three different discourses, primarily stemming from the environmental (e.g., increase of material circularity) and partially from the governance dimension (e.g., setting targets for CE transition).

Table 2: Distribution of indicators with regard to reference levels (own analysis)

Level of reference	Absolute frequency	Relative frequency
CE-specific assessment	152	37%
General sustainability assessment	142	35%
Both	114	28%

The investigation into whether the identified 408 indicators relate more to a CE-specific or general sustainability assessment reveals the following (see Table 2): More than a third of the indicators can be assigned to one of the two categories. In addition, just under a third of the indicators relate to both approaches.

Finally, when analysing the relation of each indicator to the ten R-Strategies described in chapter 2, the following picture appears (see Table 3): Although the first two R-Strategies (R0-Refuse and R1-Rethink) represent the most important from a CE perspective, up to now they are essentially not covered in legal, practical and scientific frameworks. No indicator related to R0 was present; only three indicators related to R1 have been identified. Furthermore, all other strategies that are lower in the hierarchy than these two (R2-R9) receive more attention, with strategies R4 (Repair) and R8 (Recycle) having the greatest prominence.

Table 3: Indicators' relations to R-Strategies (own analysis)

Relation to R-Strategy	N/A	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9
Absolute frequency	218	0	3	61	54	89	68	63	60	81	48

5 Discussion

The integrated framework described in the previous chapter presents a broad set of criteria and indicators to support the transition to circular GSVCs. By bringing together different discourses with different foci in relation to CE criteria and indicators, it has been possible to develop a comprehensive catalogue that addresses various relevant dimensions. In addition to CE-specific aspects, the framework also includes more general sustainability-related aspects. This counter-acts the disconnection problem between general sustainability performance and circularity performance assessment frameworks and enables a synergistic consideration of circularity and other sustainability aspects. The integration of legal, practical and

academic perspectives has thus proven to be an effective approach to provide a more holistic view.

Despite these positive aspects and the existing breadth of the set, some gaps have been identi-fied. On the one hand, this concerns the need for greater elaboration of the social dimension. On the other hand, further criteria and indicators need to be integrated that relate to the most important, but so far hardly considered, R-Strategies R0 and R1. The latter underlines the already emphasised need in literature to integrate new targets that go beyond recycling and efficiency improvement approaches. However, it should be noted that these strategies are associated with business model transformations, and therefore, the extent to which supply chain management is a good starting point for this must be examined. Beyond that, when looking more detailed at the level of indicators, it becomes obvious that some indicators are not yet specified enough to enable clear measurement and therefore need specification (e.g., "water emissions"). In addition, there are sometimes only subtle differences between various indicators, highlighting the need to identify the most suitable ones. While the breadth of the existing set can certainly be seen as a strength in the sense of comprehensiveness, it also represents a challenge for implementation in business practice. A future reduction of the framework to prioritised aspects, determined, for example, with the help of a participatory research approach, could provide a remedy here. Besides these content-related challenges, some methodological limitations are also present: As the framework developed is based on a limited selection of 12 documents, it is possible that additional important aspects from other references have not been included. Furthermore, all statements made in the previous and this chapter refer to the analysis of these selected sources and therefore only hold true for them. An enrichment with other documents is therefore advisable. In addition, when considering the demarcation of the foci of the academic, practical and legal discourse, it should be kept in mind that these also have links to each other. Another important methodological limitation is the subjectivity in the formation of clusters and assignments to them as part of the framework creation. This could be counteracted with a future external validation with experts. Finally, in very rare cases, it was not possible to incorporate identified information into the framework due to its lack of clarity. This could be rectified in future by contacting the original authors and consulting with them.

6 Conclusion

This paper dealt with the presentation and analysis of a framework to support the incorporation of circularity principles in GSVCs. It was shown that the framework covers a wide range of metrics (73 criteria and 408 potential indicators in 29 categories and four dimensions), which was made possible by the integration of three different discourses (science, practice, law). In the medium term, the framework can serve as a basis for developing industry-specific performance measurement sets and/or deriving management strategies. However, before this is implemented, future work should refine the framework by addressing important content and methodological limitations identified during the analysis. In the long term, the use of such a framework has important implications for the GSVC practice. It goes hand in hand with changes in various areas such as product design, procurement or cross-industry collaboration. Overall, the authors hope to have created a good basis for promoting more circularity and sustainability in GSVCs in the future, even if the framework still needs further refinement and therefore represents a work in progress.

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Appendix: framework summary

Category	Criterion	Exemplary indicator
Material resources	Reduce use of material resources in general	Material intensity: Amount of kg materials per product
	Decrease use of harmful/hazardous/ critical materials	% Critical inflow: (Mass of inflow defined as critical/ total mass of linear inflow) * 100
	Decrease materials' environmental impact	Materials environmental impact: Average eco-cost per kg of material
	Decrease processing environmental impact	Processing environmental impact: Average eco-cost of processing per kg of material
	Increase use of recyclable material	Fraction of cost spent on recyclable material to total cost of material
	Increase material circularity	Material circularity: (Weighted) average percentage of circular inflow and percentage of circular outflow
	Increase overall circularity	Number of circular processes/circularity gaps
Waste	Reduce waste generation	Amount of kg waste directed to disposal for landfilling, incineration or other disposal operations
	Implement environmentally sound waste management	Use of best available techniques in waste management as guiding principles
Water	Reduce water use	Water use
	Increase water circularity	Circular water use: % (by volume) of water annually used reused elsewhere
	Improve water treatment	Existence of plans to extract surplus nutrients, metals, chemicals, heat and similar valuable resources before discharging the water used
Energy	Decrease energy consumption/use of energy	Cumulative energy use
	Increase energy efficiency	Fraction of energy loss
	Use energy from renewable sources	Fraction of energy purchased from renewable sources
Land & biodiver-sity	Reduce land use change impact	Impact on deforestation
	Reduce soil use/depletion	Soil use in production
Air	Reduce air emissions	Total eco-cost of fine dust and summer smog
Plant, property, equipment and assets	Decrease inventory	Amount of inventory in kg materials at a specific point in time
	Use “green” equipment/technology	Acquisition of long-lasting and durable equipment
	Use plant, property, equipment and assets that support circular products and services	Description of management status on digital systems that support circular products or services
	Use circular assets	Acquisition of second-hand equipment
	Apply circular asset management	Policies or agreements in place that enable recirculation for the end-of-use of assets in practice
Carbon footprint	Reduce CO_2e emissions	Total GHG produced per kg product

Category	Criterion	Exemplary indicator
Product	Environmentally friendly and circular product design	Product lifetime: The time period the product functions as desired by the user
	Environmentally friendly product delivery	Number of empty trips in delivery
	Environmentally friendly product use	Availability of environmental instructions
	Maintenance of functional performance	Precautions for use
	Product recovery	Rate of actual product recovery by recovery type
Services	Availability of services to enhance environmental sustainability and circularity	Provision of technical support
Costs	Reduce costs	Average materials price per kg of material
Revenues	Increase revenues	Revenue from upgrade, repair and maintenance services of products
Profits	Increase profits	Profits from recovery activities, including remanufacturing, recycling and disposal
Growth	Increase market share	Market share
Profita-bility	Increase profitability	Rate of return on capital
Risk	Reduce risks	Availability of assets/equipment
Efficiency	Increase the efficient use of supply chain assets	Capacity utilisation: Output in kg materials per time period/Total available capacity in kg materials per time period
	Increase time-efficiency	Production time
Producti-vity	Decoupling of financial performance and linear resource consumption	Circular material productivity: Revenue/Total mass of linear inflow
Quality	Increase quality	Quality level of production
Customer	Increase customer satisfaction	Customer satisfaction
	Increase customer loyalty	Customer loyalty
	Increase customer purchase intention	Customer purchase intention
	Increase customer retention	Customer retention
Finance & invest-ments	Sustainable investments	Capital invested in sustainable solutions
	Finance for circularity	Fraction of cost spent on CE technology to total cost of investments
Health and safety	Employee-related health and safety compliance	Number of accidents/incidents in manufacturing
	Safe and reliable product use for customers	Number of incidents of consumer complaints
People and skills	Increase in training	Amount of training provided on CE
	Provision of employment opportunities	CSC jobs created: Number of fixed and variable jobs
	Provision of decent work	Fair wage level
	Provision of benefits for employees	Expenditure on benefits for employees
Contribu-tion to local economy	Increase ethical and local sourcing	Fraction of local suppliers
	Increase donations to local communities	Donations to local communities

Category	Criterion	Exemplary indicator
	Foster socially compatible recovery processes	Fraction of domestic value recovery
Sustainable management	Implement economically sustainable management (of CSC)	Identification of explicit economic performance goals
	Implement environmentally sustainable management (of CSC)	Identification of explicit environmental performance goals
	Implement socially sustainable management (of CSC)	Identification of explicit social performance goals
Communication	Sensibilise workforce about CE-related topics	Internal communication channels used for CE messaging
Innovation	Involve leadership in supporting CE innovation/development projects	Individuals leading innovation projects have the mandate from top management to work on CE innovation and regularly report to top management on circular innovation KPIs
	Embed CE principles in innovation/development projects	Existence of tools for supporting CE innovation/development projects
	Collaborate on circular innovation/development projects	Existence of formal collaboration structures
	Integrate relevant data into circular innovation/development projects	Existence of data systems for supporting circular innovation/development projects
Strategy and planning	Centrality of CE to the CEO's agenda	Mentioning of CE (or relevant concepts) in external communication
	Align company strategy to CE	Mentioning of CE (or relevant concepts) in strategy documents
	Set targets for CE transition	Identification of explicit circular performance goals
	Support CE implementation	Corporate Circular Reporting (Y/N)
	Be transparent	Public availability of CE-related company documents
External engagement	Engagement with suppliers to increase sourcing based on CE principles	Existence of verifiable formats of engagement
	Engagement with customers advancing CE topics	Existence of verifiable formats of engagement
	Engagement with policymakers to support the transition to a CE	Existence of verifiable formats of engagement
	Engagement with external investors and/or financiers on CE topics	Existence of verifiable formats of engagement
	Membership or active engagement with CE-related initiatives	Proof of membership or active engagement
Legend: Green = Environmental dimension; Grey = Economic dimension; Orange = Social dimension; Blue = Governance dimension		

Category	Criterion	Exemplary indicator
References: *Legal regulations* – ESRS 5 of CSRD (European Commission, 2022); EU Regulation on Shipment of Waste (European Commission, 2024a); Ecodesign Directive (European Commission, 2024b); EU Right-to-Repair Directive (European Commission, 2024c); *Practical frameworks* – Circulytics (Ellen MacArthur Foundation, 2020); CTI (World Business Council for Sustainable Development, 2023); *Academic frameworks* – Calzolari et al., 2022; Lahane et al., 2024; Lee et al., 2024; Montag & Pettau, 2022; Primadasa et al., 2024; Vegter et al., 2023		

A T-Shaped Perspective for Building Holistic Sustainability Reporting in the Digital Era

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In the last three decades, the increasing attention around the sustainability has stimulated several international debates about the topic of performance measurement approaches. With the aim of conceptually addressing the multiple challenges behind sustainability performance measurement, the paper explores how recent sustainability reporting regulations, particularly the Corporate Sustainability Reporting Directive can foster a holistic approach. Thanks to the support provided by the T-Shaped logic and the Systems-Thinking approach, a conceptual model is proposed to analyse role, condition, and contribution of ongoing digital transition on sustainability management and sustainability performance measurement. Reflections herein provide insights for researchers, professionals, and policymakers on integrating specialized skills with broader capabilities to better capture the contextual and subjective dimensions of sustainability. The originality lies in proposing an innovative conceptual framework for bridging specialized competences with inter- and multidisciplinary capabilities in sustainability reporting.

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1 Introduction

Over the past decades, the persuasive nature of sustainability has sparked a multi- and interdisciplinary debate involving several research communities from multiple scientific fields (Saviano *et al.*, 2017). Scholars and professionals have progressively focused their attention on the ways through which quantifying and measuring the 'dimensions' of sustainability (Mura *et al.*, 2018). Taking note about the increasing relevance that sustainability performance measurement is acquiring for practitioners, researchers, and policy makers, it is important to highlight the intrinsic economic and social complexity of sustainability and sustainable development (Caputo *et al.*, 2018), and on the need to adopt a holistic approach for capturing their peculiarities (Hadorn *et al.*, 2006). In contrast to this need, it seems that current approaches to defining of sustainability performance indicators is affected by a predominantly reductionist approach, as shown in the current European Directive (Gnanaweera & Kunori, 2018). In such a direction, the Corporate Sustainability Reporting Directive (CSRD), aims to expand the scope of companies subject to sustainability reporting obligations (Hummel & Jobst, 2024) and to define a common perspective for measuring economic, social, and environmental impacts without considering the context and subject-specific features of companies subject to the new regulation (Pantazi, 2024). It seems that the CSRD suffers from a highly specialized approach that does not consider external environment as a relevant factor that affects companies' approach to performance measurement (Pizzi & Coronella, 2024). Following these preliminary reflections, the paper aims to enrich the existing literature on sustainability performance measurement by underlining how the CSRD can represent a catalyst in the evolution from a reductionist approach to a holistic one, reflecting the core principles of sustainability science. In such a vein, this contribution wants to address the following research question: "How can specialized competencies be integrated with inter- and multidisciplinary capabilities for ensuring and effective, viable, and participative approach to sustainability reporting?"

In particular, the research contributes to the conceptual advancement in the field by integrating the T-shaped model and the Systems-Thinking approach in the research field of sustainability science. Additionally, digitalization is approached as a key driver to implement effective and pragmatic sustainability actions (Caputo *et al.*, 2023). In summary, the rest of the paper is structured as follows: Section 2 provides the theoretical background on which reflections herein are developed; Section 3

briefly describes methodological approach adopted; Section 3 proposes a possible conceptual model, and Section 4 presents preliminary conclusions of reflections herein.

2 Theoretical Background / Literature Review

In today's world, where sustainable development is becoming more complex and interconnected, sustainability science is stepping up as a vital field that blends different disciplines and approaches. Its goal? To create both theoretical and practical knowledge that crosses the usual boundaries of various fields (Barile *et al.*, 2018). This approach pushes back against the narrow focus of individual disciplines, which often fall short when tackling big global issues like climate change, biodiversity loss, resource depletion, and social inequality (Freund *et al.*, 2024). Grounded in systems theory, sustainability science is all about solving problems rather than sticking to traditional academic silos (Aronson, 2011). It calls for teamwork among universities, policymakers, businesses, and communities (Spangenberg, 2011). This shift emphasizes the need for transdisciplinarity as a key scientific principle, allowing for the blending of various knowledge sources to collaboratively tackle complex societal challenges (Lang *et al.*, 2012). In this context, recent changes in European regulations have helped shape a more comprehensive view of sustainable development, sparking international discussions on how to integrate multidisciplinary, interdisciplinary, and transdisciplinary approaches (Yarime *et al.*, 2012). According to Golinelli *et al.* (2015), it's crucial that science, politics, business, and society collaborate closely, especially in corporate and institutional decision-making ().

In today's ever-changing landscape, the Corporate Sustainability Reporting Directive (CSRD) marks a significant regulatory change through the principle of double materiality. This means organizations must report not only on how their activities impact environmental and social systems but also on how sustainability issues influence their financial performance (Baumüller & Grbenic, 2021). It takes the place of the Non-Financial Reporting Directive (NFRD) and greatly expands the scope and responsibilities of sustainability reporting, now including all large companies and listed small and medium-sized enterprises (SMEs). This duality adds a layer of complexity to sustainability reporting, especially with the digitalization requirements (like XBRL tagging) aimed at enhancing transparency and comparability (Atanasov,

2023). Tackling this complexity calls for a model that can effectively bridge both depth and breadth of knowledge—a challenge that the T-shaped model is well-suited to meet.

The T-shaped concept, which was initially introduced to describe professionals who possess deep expertise in one area (the vertical bar) while also having broad collaborative skills across various fields (the horizontal bar), could be a valuable framework for understanding sustainability reporting (Barile *et al.*, 2012; Barile *et al.*, 2016). Unlike "I-shaped" specialists, T-shaped professionals are better equipped to navigate systemic complexity, integrate knowledge from different areas, and facilitate more comprehensive decision-making. In the context of the CSRD, this model provides a conceptual foundation for interpreting the relationship between technical ESG compliance and strategic sustainability management. While the vertical competencies tackle the regulatory and data-intensive requirements of the directive, the horizontal aspect enables organizations to incorporate sustainability into broader strategic and stakeholder considerations.

This means that fostering T-shaped skills within organizations helps them better integrate digital technologies, balance data and insights, and manage both regulatory and innovation challenges in sustainability (Saviano *et al.*, 2019a). Even though there's increasing focus on these dynamics, more research is essential to delve into the cognitive and subjective factors that influence digital transitions in sustainability reporting and how these factors interact with the changing regulatory landscape (Hristov & Searcy, 2024).

3 Methodology

This study takes a conceptual and interpretative approach, grounded in systems thinking and enhanced by a transdisciplinary perspective (Bryman, 2016). Instead of leaning on empirical data, the paper offers a theoretical reflection that delves into how recent changes in sustainability regulation -particularly the CSRD- can shift from a reductionist viewpoint to a more comprehensive framework that aligns with the fundamental principles of sustainability science.

The methodological design utilizes T-shaped logic (Barile *et al.*, 2012; Barile *et al.*, 2016) as an interpretive model that effectively combines depth (specialized knowledge) and breadth (interdisciplinary insight) in the field of sustainability performance measurement. Through this perspective, the research introduces a conceptual model that links three essential elements: (1) the epistemological foundations of sustainability science; (2) the regulatory demands of the CSRD; and (3) the supportive role of digitalization processes.

Moreover, thanks to the insight provide by the systems-thinking approach (Barile *et al.*, 2018), the proposed model is built on recursive reasoning that reflects the ongoing interaction between individual and collective viewpoints.

4 Results and Discussion

By adopting the 'T-shaped' logic, organizations could overcome a reductionist view on which sustainability performance measurement seems to be actually based through the synergistic integration of both vertical capabilities and horizontal competencies. In such a direction, the T-shaped offers the opportunity for capturing and understanding the multiple dimensions of sustainability combining individual approaches within collective expectation (Caputo *et al.*, 2019).

Following this conceptual line, it clearly emerge they key role that digitalization processes and the digital technologies can have in ensuring the combination between actors and community through recursive loops. Thanks to the digital technologies it is possible to link horizontal trans-disciplinary approaches to sustainability with vertical specialized capabilities required by the sustainability reporting guidelines without reducing sustainability performance measurement to 'simple' standard to which align companies' behaviors and decisions (Caputo *et al.*, 2021).

The digital age offers an effective opportunity for shifting from a reductionist to a holistic view through the promotions of extensive participation based on the active contributions of all the stakeholders interested in sustainability performance. In such a vein, the correct implementation of the CSRD becomes a catalyst for this paradigm shift, emphasizing the importance of integrating quantitative and qualitative dimensions through digitalization. By combining a multidisciplinary horizontal perspective with the vertical and technical competencies of the actors involved in

sustainability communication, the CSRD fosters a better balance between strategic objectives and actors' specialization. This synergy not only simplifies compliance with regulations but also enables organizations to provide a holistic understanding of the three-dimensional impacts.

The conceptual logic through which such a change is possible is show in Figure 1.

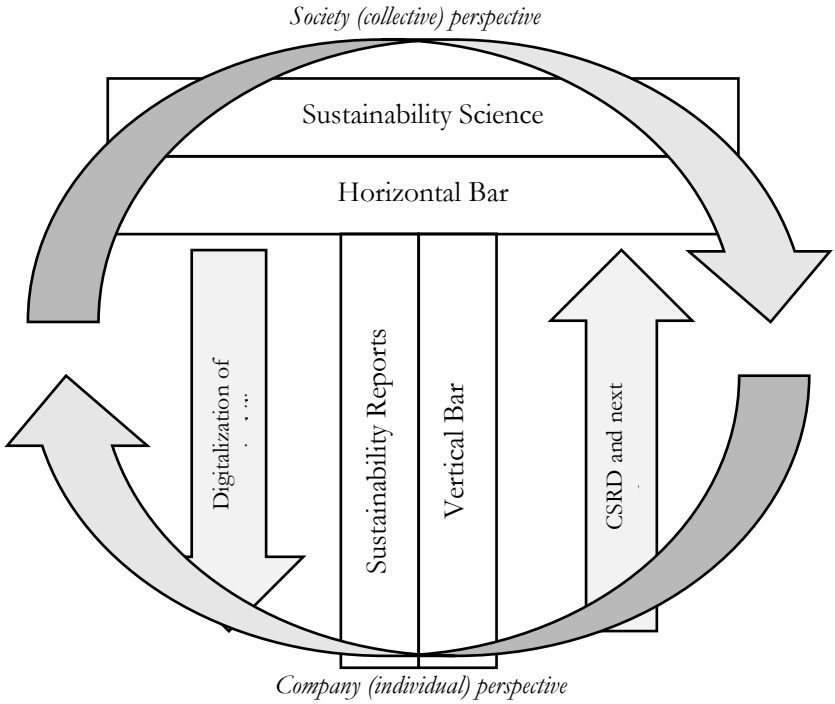

Figure 1: The conceptual model
Source: Authors' elaboration, www.asvsa.org

The model shown in Figure 1 outlines the recursive path on which sustainability is based. According to the model, sustainability reports can be considered as an 'artifact' of sustainability science and their features cannot be analyzed without considering the ways in which 'Society (collective) perspective' and 'Company (individual) perspective' interact. Thanks to this representation it is possible to depict the role that digitalization and sustainability guidelines have in the evolutionary path of sustainability science and behaviors. Basically, while digitalization acts as a catalyst

of sustainability science offering the opportunity for developing tangible outcomes, instruments, and tools that companies and individual actors can use, on the other side, the CSRD and the next sustainability reporting guidelines should be 'abstract' actors' expectations through the definition of an average levels on which to build the next steps in the evolution of sustainability science.

5 Conclusions

For a long time, sustainability has been approached in social and managerial studies in terms of standards to which align companies, organizations, and actors behaviors (Caputo *et al.*, 2020). This approach can be considered as the consequence of a widespread reductionist approach interested in standardized social dynamics through the definition of common protocols and unique rules through which define metrics and rankings (Saviano *et al.*, 2019b). Such approach is unable to catch the multiple dimensions of sustainability and its application with references to the sustainability disclosure and reports has only produced multiple divergent guidelines increasing complexity for companies and practitioners.

Thanks to the adoption of the T-shaped logic and the Systems-Thinking approach the paper has outlined the possibility for linking collective and individual perspective in a common framework clarifying – at the same time – the key role that digitalization processes and reports guidelines could have in ensuring an effective and viable evolution of sustainability science.

The model only aims to clarify the conceptual logic on which the increasing effort of practitioners, researchers, and policy makers about sustainability should be based. In line to this purpose, the paper also wants to recall the attention on the need for recombing individual and collective perspectives under the common framework of sustainability science (Caputo *et al.*, 2023b). Without this expected balance, sustainability risks losing its identity and could become another useless standard unable to give the attention to the changing dynamics of socio-economic evolution.

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The Impact of Global Crises on Employment and Talent Needs in the IT Sector: A Time-Series Analysis of COVID-19 Disruptions and AI-Driven Adaptations

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This paper looks at how the COVID-19 crisis has affected jobs in the Slovak IT sector between 2013 and 2023, focusing on trends, regional differences, and remaining vacancies. Using time series analysis and ARIMA modelling, it examines employment changes over time and predicts future developments. In addition, the study conducts a regional analysis to examine differences between Slovak regions and a job vacancy analysis to uncover the need for new talent. The results show that IT employment temporarily declined during the peak of the pandemic in 2020 but quickly bounced back, largely due to telework and digitization efforts. As for regional differences, while Bratislava and other large cities have more IT employment, smaller cities struggle more with employment shortfalls. Despite the sector's resilience, vacancies remain problematic, signaling a mismatch between demand and available talent. Forecasts suggest modest employment growth in the IT sector, but uncertainty in the economy may pose a risk. The study highlights the need for targeted policies to address labor shortages and improve skills, especially in smaller cities. By analyzing the impact of crises, vacancies, and future employment trends, this research offers valuable insights for policymakers and businesses aiming to strengthen the IT workforce in Slovakia.

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1 Introduction

The COVID-19 pandemic brought with it a variety of unexpected challenges that impacted various sectors, including the technology sector (Trenerry et al., 2021). The IT sector has played one of the most important roles in enabling teleworking (home office) for compliance with social isolation measures. This transition has led to a rethinking of traditional working patterns and an increased reliance on freelance work (Evans, 2020; Franco et al., 2023). Concurrently, it has precipitated an escalation in the demands placed upon the competencies of employees within the IT sector, as enterprises have endeavoured to optimise flexibility to contend with economic turbulence (Alpar & Osterbrink, 2020). These trends have reshaped workforce needs, requiring IT professionals to develop new skill sets in areas such as machine learning, data analytics, and AI governance (Brynjolfsson et al., 2025). Given these global shifts, our study focuses on employment trends within the IT sector in Slovakia. We analyse the impact of the COVID-19 pandemic on employment dynamics, accounting for changes in the need for certain skills, worker flexibility, and job openings. Using the ARIMA (Autoregressive Integrated Moving Average) model, we perform a time-series analysis to assess how the pandemic has affected employment trends in the Slovak IT sector. Our findings aim to shed light on workforce evolution to help policymakers and businesses better understand the pandemic's long-term effects on the labour market.

2 Literature review

The COVID-19 pandemic has resulted in significant changes in talent management and recruitment as organizations adjust to changing skill requirements, the move to remote working and financial constraints. Hiring freezes, layoffs, and pay cuts have occurred, causing workforce instability and increased employee stress (Aguinis & Burgi-Tian, 2021; Kajwang, 2022; Singh & Ahmad, 2021; Adelaine et al., 2024). The lack of clear work-life boundaries has led to an increase in burnout and highlighted the shortcomings of traditional performance appraisal methods (Aguinis & Burgi-Tian, 2021; Singh & Ahmad, 2021).

The IT sector has witnessed a remarkable rise in the demand for experts because of the pandemic-induced boom in the usage of digital technology. Job applicants have been aggressively looking for roles within industries that were minimally affected by the crisis. At the same time, more people have been interested in working from home because of health concerns and lockdowns (Hensvik et al., 2020; McFarland et al., 2020). Consequently, organizations have rushed to adjust to the new working-from-home setting, thereby accelerating the demand for cloud computing, cybersecurity, and remote work collaboration tools (Wang, 2022; Pavashe et al., 2023). Conversely, there has been heightened competition in the labor market, with individuals from other fields starting to switch to the IT industry (Aguinis & Burgi-Tian, 2021; Fernandes et al., 2022).

Companies have been compelled to explore new talent management approaches to enable them to retain able employees and enhance their responsiveness in the dynamic work environment context. They had to deal with issues such as work stoppages, layoffs, and the shift to telecommuting, which meant that they had to change the way they searched for and retained talent (Aguinis & Burgi-Tian, 2021; Vaiman et al., 2021).

With the disruption of conventional workforce arrangements, organizations have embraced more dynamic performance measurement approaches and innovative workforce management practices, including multi-source appraisal systems and contingent talent management approaches (Sigala et al., 2023; Kajwang, 2022). These not only offer solutions to immediate problems of maintaining an adequate workforce level but also help businesses remain competitive in an ever-evolving labor market (Malathi & Millath, 2020). These developments are often indicative of the reality that the processes by which organizations find, manage and retain talent have been fundamentally transformed, reaching far beyond the confines of IT and into every corner of the economy. (Vaiman et al., 2021).

3 Methodology

This section describes the research design, data collection, data structure, and methods used in this study. The Web of Science database was selected as the primary source for identifying relevant articles related to the impact of the global crisis on

employment and talent needs in the IT sector. The search was restricted to peer-reviewed academic journal articles published in English that included the terms ("COVID-19" OR "pandemic") AND ("IT sector" OR "IT employment") AND ("talent management" OR "labour market") in their title, abstract, or keywords.

The data for this study were sourced from the statistical database Datacube.sk and pertain to Slovakia. Our analysis focused on the average number of employed persons and the number of job vacancies in the IT sector, categorized according to the SK NACE classification. The SK NACE classification is a system used in Slovakia to categorize economic activities, providing a framework for statistical data collection and analysis across various sectors. This classification is crucial for understanding sectoral dynamics, financial health, and economic performance in Slovakia. The SK NACE classification helps identify clusters of sectors with similar patterns of indebtedness. In Slovakia, sectors such as C, F, G, and H, which belong to the tertiary sector, and sectors K, R, and S, part of the secondary sector, have been identified as having homogeneous debt patterns. This clustering is significant for benchmarking and understanding sectoral stability and independence, which is vital for economic growth in the V4 nations (Gajdosiková et al., 2024). For our analysis, we use data from sector J, which is the Information and Communication sector according to the SK NACE classification, encompassing activities such as publishing, telecommunications, software development, IT services, and information-related activities.

To examine employment trends and make predictions, we developed an ARIMA model based on the data on the average number of employed persons. This approach enabled us to identify patterns and forecast employment dynamics within the Slovak IT sector. The Autoregressive Integrated Moving Average (ARIMA) model is a widely used statistical tool for modeling and forecasting time series data. It combines three components: Autoregressive (AR), Integrated (I), and Moving Average (MA) models. The AR component involves regressing the variable on its own lagged values, the I component involves differencing the data to make it stationary, and the MA component models the error term as a linear combination of error terms from previous time steps (Liu et al., 2020; Cao, 2024; Liu, 2024).

4 Results

The **Fig.1** shows how the average number of employees in the IT sector has changed in different regions of Slovakia between 2013 and 2023. The Bratislava region (blue) is the most important center of the IT industry in Slovakia. The number of employees in the IT sector was 21,732 in 2013 and has been growing steadily, with some small changes. After a small decrease in 2018-2019, growth increased again, and 2022 reached the highest value in the monitored period. The Košice region (brown) is the second most important IT center in Slovakia. It had 5,308 employees in 2013 and was growing steadily until 2019.There was a significant jump in 2019-2021.This growth may have been supported by increased digitization during the pandemic and the expansion of IT companies in the region. The Žilina region (light blue) showed steady growth. The Trnava region (orange) had a total It had 1,878 employees in 2013, and this increased to 2,369 by 2021, but then went down to 1,638 in 2023, which is lower than in 2013. The Trenčín region (grey) has seen steady growth from 915 employees in 2013 to 1,428 in 2023, indicating a slight strengthening of the sector. The Nitra region (yellow) grew from 1,191 employees in 2013 to 2,269 in 2021, but then went down to 1,728 in 2023, which may be related to people leaving the area. The Banská Bystrica region (green) shows a fluctuating trend from 2013 to 2019. The Prešov region (dark blue) had the smallest number of employees in the IT sector. The **Fig. 1** shows that the Bratislava and Košice regions are the main IT centers in Slovakia. Other regions show moderate growth or stagnation, and some regions, such as Nitra and Trnava, saw a decline after 2021. This may be because of the effects of the pandemic, which might have led to a temporary increase in demand for IT services and jobs.

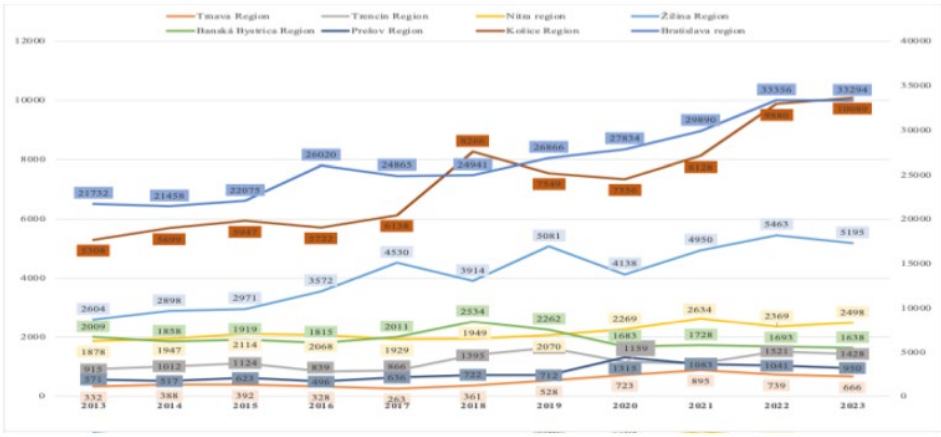

Figure 1: Average number of employees in the IT sector in Slovak regions (2013-2023)
Source: datacube.sk, own processing; Number of employees in all regions shown on the primary (left) axis; Bratislava region shown on the secondary (right) axis due to significantly higher values.

The **Fig. 2** shows the number of available jobs in the IT sector in Slovakia between 2013 and 2023, with significant fluctuations. The lowest point was in 2014 (221 positions), which may be related to lower demand for IT specialists, while the highest point was in 2018 (544 positions), probably due to the growth of technology firms and digitalization. After 2019, the number of available positions declined, reaching only 303 in 2020, which could be due to the COVID-19 pandemic. Subsequently, from 2021 onwards, the demand for IT professionals grew again, reaching 468 positions in 2022. This development can be compared with employment growth in the IT sector (**Fig. 1**), where Bratislava region and Košice region have seen a steady increase in jobs, while Nitra region and Trnava region have seen a decline after 2021.A rise in employment was observed in the Košice region in 2019–2021, which is consistent with a rise in the number of open positions in 2021–2022. The trend line indicates a long-term slight growth of job opportunities in the IT sector. All things considered, the dynamics of the number of open positions in the IT industry reflect the effects of the pandemic and digitization.

Figure 2: Average number of available jobs in the IT sector in Slovakia (2013-2023)
Source: datacube.sk, own processing

The decomposition of multiplicative time series, as shown in **Fig. 3**, analyzes how global crises have affected employment trends and talent requirements in the IT industry. Data are divided into four main components: observed values, trends, seasonal variations, and random fluctuations. According to the data, IT employment is on the rise overall, though it experiences occasional fluctuations that reflect recurring patterns in the labor market. Also, the trend component shows a long-term rise in IT employment. The pace slowed down in 2020-2021 because of the pandemic-disrupting impacts of COVID-19. This was the period in which the jobs market was adapting, had job losses, freezing of recruitments, and a massive switch to remote working. All these modifications are altering the dynamics of employment. The seasonal component, which normally shows predictable fluctuations, deviates during the pandemic, suggesting disruptions in workforce demand and hiring cycles. Uneven fluctuations are captured by the random component, which is especially volatile in 2020–2021. This showcases the volatility the crisis has caused, as companies rapidly changed their hiring practices in the wake of unstable economic conditions. But post-pandemic employment data show not just a recovery but an acceleration of job growth, fueled by the growing adoption of AI-driven technologies. Having been handed an altered requirement for IT professionals, companies have directed themselves towards digital transformation and automation. Fields like data science, cybersecurity, and cloud computing emerged due to AI, with a vision of the work role and capability. Upskilling continuously and being flexible are required skills to adapt to this inevitable robotic assault for the IT professionals as the processes fueled by AI continue to consume most branches of the business.

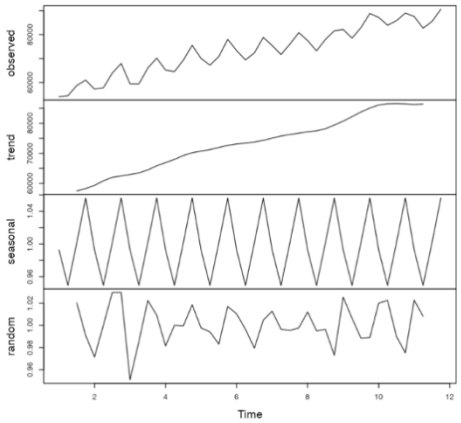

Figure 3: Decomposition of multiplicative time series for IT sector employment
Source: own processing

The box plot, as you can see in **Fig. 4**, provides a clear picture of how employment in the IT sector fluctuated across the four quarters (Q1–Q4) from 2013 to 2023. As we can see from the data below, there are also clear seasonal patterns, with the median employment low occurring in Q2 and high occurring in Q4. That indicates IT employment typically falls during the second quarter, perhaps thanks to summer slowdowns, before peaking at year's end, when companies increase hiring to meet project deadlines and budget cycles. Also note the difference in variation between quarters. Q1 and Q3 exhibit larger swings, suggesting moments of greater turnover, while Q2 is more stable, indicating more consistent employment. The general trend shows cyclical behavior in IT employment with seasonal variation in the data. The 2020–2021 COVID-19 pandemic interrupted these trends briefly due to interruptions. Throughout that period, hiring slowdowns in the pace and restructuring of staff generated additional volatility, interrupting the seasonally normal trend. As the industry adapted, though, not only was employment restored but also expanded, driven in part by increased investment in AI-driven solutions and digitalization. These trends have reshaped demand for the workforce, favoring the greater demand for AI-skilled capabilities and flexibility within the IT sector.

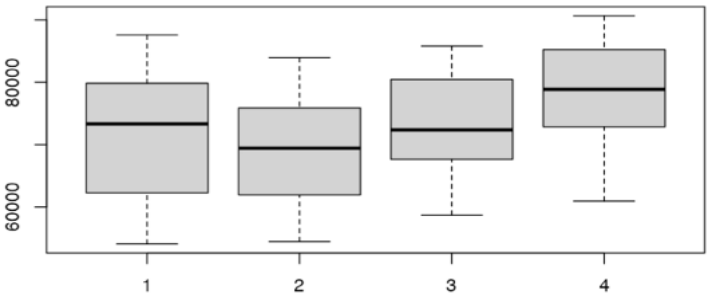

Figure 4: Box plot
Source: own processing

The ARIMA model employed as ARIMA (1,0,0) (0,1,1) [4] with drift, as you can see in **Fig. 5**, is applied to forecast time series, giving insight into the impacts of global crises, such as the COVID-19 pandemic, on jobs and talent needs in the IT sector. The model incorporates both non-seasonal and seasonal components to capture underlying trends and cyclical behavior within the data. The seasonal period of 4 represents quarterly data, picking up any cyclical patterns in employment or talent requirements that overlapped with fiscal quarters or other periodic factors. The drift term of the model assumes that the data have a long-run tendency, and this tendency is a slow rise or fall with the progression of time. It is especially important in the tech industry, as worldwide pandemics like COVID-19 have massively disturbed and changed employment patterns. The model forecasts give valuable insights regarding future trends so that stakeholders can forecast changes in the employment levels, talent supply, and other key numbers. The world crisis, e.g., the COVID-19 pandemic, has heavily impacted the IT industry. At first, demand for IT services increased due to the remote work and digitalization shift. However, budget constraints and financial uncertainties have also led to hiring freezes and layoffs in some industries. In addition, the evolution of Artificial Intelligence (AI) has helped in two capacities in terms of IT employment. Firstly, AI has opened new jobs in fields like machine learning, data science, and AI programming. On the contrary, AI automation has led to job replacement of some work, particularly jobs with repetitive tasks. This cyclical interaction between AI innovation and economic dynamics continues to shape the IT employment market.

By using this ARIMA model, policymakers can forecast the potential long-term effects of global crises on the IT job market. For instance, when the forecast reveals a decrease in employment, organizations can invest more in AI-based transformations and automation to counter the effect of falling demand for labor. Conversely, a favorable trend in the demand for talent can initiate intense recruitment and training efforts to offset talent deficits and foster an equilibrium workforce. In conclusion, the ARIMA (1,0,0) (0,1,1) [4] with drift model provides a rational and methodical approach to analyze and predict the complex phenomena of the IT sector's response to global crises. With its ability to record trend and seasonality elements, is an important tool for forecasting and planning in the context of ongoing disruption and increasing role of AI-driven adjustments in shaping the future of work.

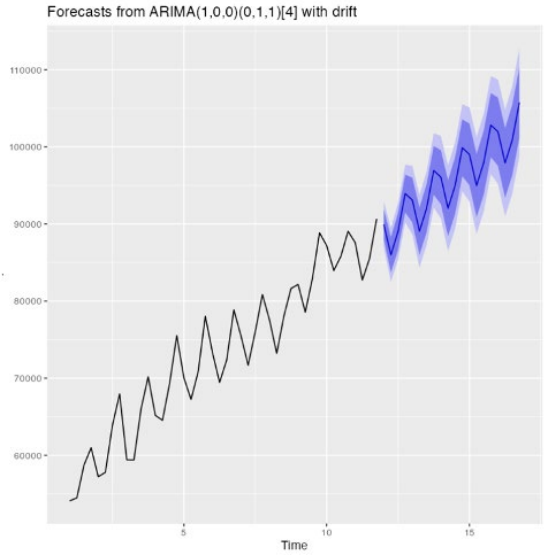

Figure 5: Automatic ARIMA forecasts
Source: own processing

5 Discussion

Our findings indicate that the COVID-19 pandemic caused a short-term decline in IT employment in Slovakia. However, the sector quickly resumed, with high resilience being observed. Mura et al. (2022) note that the pandemic led to a sharp

increase in unemployment in most sectors of the Slovak economy, particularly the industrial sector. On the other hand, Kiner & Štefaník (2022) point out that the intrinsic flexibility of the IT industry and its reliance on digital infrastructure allowed it to recover quickly. IT professionals and technicians were relatively well insulated from the pandemic's economic dislocations.

A key finding of our study is that the shift to remote work and accelerated digitalization helped mitigate job losses and even created new employment opportunities in IT. Balsmeier & Woerter (2019) argue that digitalization has increased employment for high-skilled workers, as new tasks generated by digital technologies often complement their expertise. However, it has simultaneously reduced employment for low-skilled workers, resulting in a slightly positive net effect on overall employment. Furthermore, Braesemann et al. (2021) note that the rise of remote work has contributed to global job market polarization. Employment is increasingly concentrated in large cities and regions with strong digital infrastructure, while rural areas lag.

Our ARIMA projections suggest moderate employment growth in the IT sector, although economic uncertainties could impact these estimates. Tsuboi (2020) and Gumata & Ndou (2017) admit that in the IT sector, uncertainties can slow down economic growth and affect employment dynamics. Persistent uncertainty can lead to a reallocation of employment between sectors, often resulting in a decline in private-sector employment.

Additionally, AI is redefining talent needs, with greater need for data science, cybersecurity, and AI deployment skills. Businesses are calling for more workers who can use AI strategically, pointing to the need for continuous upskilling and reskilling. Jadhav & Banubakode (2024) believe that with emerging AI technologies, the need for specialists in AI development and data analysis will continue to grow. These roles are essential for maintaining and creating AI-driven business operations and innovation. Upadhya (2024) and Olutimehin et al. (2024) also highlight that successful AI implementation requires people who can transcend challenges in data governance, ethical challenges, as well as successful AI strategies. As such, investment in AI education, digital skillset training, and talent mobility will be essential in the long run to maintain the industry's growth and competitiveness.

6 Conclusions

This research has examined the impact of the COVID-19 pandemic on demand for talent and trends in employment in Slovakia's information technology sector. Through time-series analysis and ARIMA model techniques, the study has presented the overview of the variations in employment, geographical disparities, and shifting demands for IT professionals.

The results show that although IT employment slightly decease in the short term during the peak of the 2020 due to pandemic, it recovered quickly, demonstrating the resilience of the sector. Remote working and accelerated digitisation minimised job losses and created new ones. Regional imbalances persist, with Bratislava and Košice performing well as IT centres, but delayed regions such as Nitra and Trnava stagnate or deteriorate after 2021, and special talent development strategies outside the metropolises are called for.

Job vacancy analysis shows that IT professionals are in high demand, but there is a shortage of skilled talent, which is one of the factors driving the labour shortage. The development of artificial intelligence is changing the demand for the skills of IT specialists. Among the most important are skills in data science, cybersecurity and cloud computing. Continuous re-skilling of the existing workforce is needed to properly address the changing demands of the industry.

The ARIMA projections point to modest long-term employment growth in the IT sector. However, these forecasts would be affected by uncertainty in the domestic and global economy. Businesses and policies are required to be adaptable to keep pace with new trends. Investments in AI training, digital literacy as well as increased mobility of indigenous talent would be key to ensuring sustainable growth and competitiveness of the sector.

In conclusion, this study highlights the fundamental role of changes driven by the crisis in shaping IT work and talent needs. Further research is needed to examine in more detail the longer-term impact of AI on job displacement and creation, as well as how to improve the readiness of the workforce for digital transformation. By

reducing skills gaps and territorial inequalities, stakeholders can promote a more sustainable and inclusive IT labour market in Slovakia.

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AI AND ESG-DRIVEN GREEN INNOVATION IN THE MIDDLE EAST: OVERCOMING BARRIERS TO SUSTAINABLE TECHNOLOGY ADOPTION

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Purpose: This paper aims to explore how Artificial Intelligence (AI) can enhance synergy between green innovation, sustainable business practices, and key Sustainable Development Goals (SDGs). The study focuses on the Middle East, examining AI's role in accelerating ESG-driven green innovation, identifying barriers to sustainable technology adoption, and proposing strategies to overcome these challenges. Methodology: An exploratory research design is employed to gather data from diverse sources. Thematic analysis is used to identify recurring challenges, enablers, and best practices in the implementation of AI in green innovation. Findings: The study confirms that integrating AI within ESG frameworks significantly boosts the development of green innovations. It also highlights the importance of supportive regulatory environments and targeted training programs in enabling AI technologies to advance sustainability goals effectively. Research Limitations: The study notes a lack of in-depth analysis regarding socio-economic and cultural factors influencing technology adoption in the Middle East, which could limit broader generalizations. Implications: Findings provide valuable insights for policymakers, researchers, and industry leaders aiming to develop effective, context-specific strategies to overcome barriers in sustainable technology adoption and foster AI-driven green innovation.

Keywords:
artificial intelligence, middle east, sustainability, technology adoption, ESG metrics

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1 Introduction

For many years, the Middle East has relied on hydrocarbon economies which place oil and gas at the forefront of economic transformation and advancement. The region is now moving toward sustainable development due to global climate requirements together with economic expansion policies and Saudi Arabia's Vision 2030 and the UAE's Net Zero by 2050 strategic initiatives (Islam & Ali, 2024). The business sector recognizes Environmental Social Governance (ESG) standards as essential frameworks which organizations use to establish ethical sustainable social responsibility frameworks during their transformation. AI integration into green innovation represents more than technological progress because it needs detailed policies with sector collaboration as well as cultural changes for socio-economic sustainability. The distinctive socioeconomic together with the geopolitical setting of the area produces unique hurdles as well as possibilities to implement AI-powered sustainable technologies. Effective strategies to speed up ESG-driven green innovation require a clear comprehension of these system dynamics.

Rationale

The rationale of this research is mainly lies within a clear understanding how Artificial Intelligence and ESG principles are driving green innovation within the Middle East. It is mainly focusing on overcoming any barriers to adoption of sustainable technology adoption. The paper aims to identify how AI can accurately enhance the synergy between several aspects including green innovation, multiple business practices, and a number of sustainable development goals. The Middle East prioritizes sustainability above all else because of the rising need to combat climate change and global demands to decrease greenhouse gas emissions. AI demonstrates the powerful potential to serve this transition through energy optimization capabilities and supply chain clarity as well as environmental observation functions (Onukwulu, Agho & Eyo-Udo, 2023). It also seeks to identify practical recommendations and policy frameworks for promoting the adoption of AI and green innovation strategies, particularly for SMEs in the region.

Research Questions and Hypotheses

RQ 1: How does AI contribute to ESG-driven green innovation in the Middle East?
RQ 2: What are the key challenges faced in the Middle East region to adopting AI-driven sustainable technologies?
RQ 3: What are the processes of overcoming the raised barriers?
Hypothesis
Alternative: AI integration in ESG initiatives accelerates green innovation by improving resource efficiency and enabling data-driven decision-making.
Null: AI integration into ESG-driven initiatives does not accelerate green innovation by improving resource efficiency and enabling data-driven decision-making

2 Literature review & theoretical underpinning

The delivery success of sustainability depends on AI technologies because they increase operational effectiveness and deliver predictive information for enhanced resource allocation systems. The energy sector uses AI-driven technologies to revolutionize the production and storage as well as consumption of energy (Onukwulu, Agho & Eyo-Udo, 2023). The implementation of AI algorithms in smart grids enables real-time demand of supply balance which leads to decreased energy waste while making renewable energy sources more efficient. AI predictive maintenance organizations achieve lower downtime rates and extended infrastructure life expectancies leading to a more functional energy company. Environmental data processing through machine learning models enables individuals to optimize water distribution practices and disease forecasting in crops by assessing soil moisture and meteorological information. Farmers benefit from AI-driven analytics by making data-based choices which decrease environmental consequences with higher agricultural output results.

Organizations now use Environmental Social Governance (ESG) frameworks as their basis to incorporate sustainability through structured operation frameworks within organizational processes and decision systems. The expansion of ESG integration in the Middle East continues under pressure from worldwide investors' increasing interest as documented by Sirisha et al. (2024), along with regional demands for economic transformation and operational resilience. ESG-driven green

innovation describes the creation and deployment of technologies alongside products as well as practices which comply with ESG principles for environmental sustainability. Environmental aspects of ESG analysis concentrate on minimizing greenhouse gas emission rates streamlining resource usage and widespread adoption of renewable energy resources. Green innovation in this context encompasses advancements such as carbon capture and storage technologies, the deployment of solar and wind energy, and the creation of energy-efficient infrastructure. Artificial intelligence helps organizations by maximizing energy consumption efficiency and waste management operations while predicting equipment needs in manufacturing processes.

Artificial intelligence tools enable ESG metric monitoring as well as reporting which leads to improved corporate sustainability transparency and accountability (Johansen et al., 2022 p.2). These monitoring instruments assist organizations in measuring their carbon footprints while evaluating social performance and governance systems to maintain corporate- level compliance with worldwide sustainable goals. Multiple research works show that implementing AI-based sustainable technology solutions faces several obstacles specifically within emerging economies. The adoption of sustainable technologies faces crucial barriers from the standpoint of technological readiness and the need for regulatory frameworks as well as socio-cultural acceptance (Pham, Chuah & Feeny, 2021). Economics in the Middle East have relied on hydrocarbon industries since ancient times so they must implement both new technology alongside cultural transformations and legislative changes to become environmentally friendly. Multiple studies demonstrate that Artificial Intelligence possesses extensive potential for sustainable development though modern policies along with better infrastructure are essential to implement it on a widespread scale.

The Technology Acceptance Model (TAM)

The TAM (Technology Acceptance Model) is one significant theory that is ultimately providing a significant framework for getting a clear understanding how any individuals and also how any organizations are adopting to any new technologies. This is also including any AI and several green technologies. This is specifically relevant to the study topic as it hep to recgnsie the severa factors that may have adirect influence on the adoption of multiple technologies (Park et al. 2022). Additionally it also provide a sound knowledge on perceived usefulness, and any

external variables such as organizational culture and support. In addition to that, it also help tpo p[redict user adop[tion and allow organsiation in emnhancing digital readiness.

Research Gap

The research is mainly relies on secondary data and that is why there are few gaps as the secondary data is not porvidng the practical experineces of the workers at the workplaces. While it is provding detail insights on AI and the study tiopucbut there is a ack of numerical importantion that may be fufill in the future resarch. While the exsiting rearch also lack a deep insighst on the particular socio economic and cultural factors or aspets that may affect technology adoption within the Middle east. Through addressing these particular gaps, policymakers and reascher will be able in accurately developing targeted strategies in effectively overcoming the barriers.

3 Methodology

This study will employ an exploratory research design in this study to gather information from different sources. The missing characteristics of the topic make the exploratory design appropriate because it allows deep investigation into regional behaviour patterns. The research draws data through qualitative approaches that include both literature review studies and analysis of regional case examples. Thematic analysis will identify regular difficulties and success factors and great examples of practice through its application. The research findings will guide strategic policy-making decisions through their contribution to sustainable technology adoption knowledge within emerging economies.

Researchers have collected information from multiple groups which include stakeholders from the public policy sector together with developers who create technology as well as professionals specializing in sustainability. The research technique requires a thorough coding process which reveals common patterns about AI-driven green innovation susceptibilities alongside supportive factors while proposing concrete implementation approaches. The analysis method provides organized comprehension of the main factors which affect sustainable technology adoption by breaking down complicated stories. The researcher can obtain versatile data through thematic analysis from multiple secondary or existing sources.

Different types of data need to be analyzed because the subjective elements present uniqueness in the interpretation process. Data will be collected from 2020 till the present time which will make the study more unique. Every interpretation of data will be taken care of to avoid any misinterpretation of taken data. Thereafter, data will be collected from different kind of reliable sources which obtains proper permission to be used.

4 Results (thematic analysis)

Advantages of Artificial Intelligence in Sustainability

The Middle East faces a severe water shortage problem which AI technologies help to resolve effectively. AI systems track water consumption while detecting leaks and estimating usage demand to optimize water management procedures (Jana, 2024 p.160). AI technology deployed at regional desalination plants optimizes energy usage together with operational performance improvement. AI-affiliated mechanisms also allow to identification and sort recyclable materials, enhancing the efficiency of recycling plants and contributing to the circular economy significantly helping with monitoring the environment together with producing models to forecast climate patterns. The analysis of substantial satellite and sensor datasets through AI models enables environmental tracking atmospheric quality recording and climate change predictions (Bianchi & Putro, 2024 p.87). Decision-making authorities gain knowledge through these insights which guide their implementation of protective environmental measures. Artificial Intelligence has the potential to analyze huge datasets in a short period to breakthroughs in factors of sustainability within multiple domains. The successful utilization of AI technologies for ESG-driven green innovation by Middle Eastern countries requires solving existing barriers to achieve their sustainability goals.

Barriers Causing Obstacles in the Adoption of Sustainable Technology

Various hindrances stand in the way of sustainable technology adoption in the Middle East including regulatory restrictions together with social-emotional obstacles. Several nations face problems with their underdeveloped policies and regulations which fail to create sufficient motivation and regulatory tools to promote sustainable practices (Ogunkan, 2022). The lack of standardized guidelines for AI

integration with ESG initiatives leads to investor and business uncertainties in their efforts. The effective implementation of AI-driven solutions encounters challenges due to insufficient technological capacity which affects organizations across the region because they lack a proper framework and insufficient money and specialized knowledge to use AI technologies effectively. Rural areas face more obstacles in sustainable practices due to their limited access to digital technology because of the extreme digital divide with urban areas.

Academic institutions along with industry and government rarely work together which reduces the speed at which new technology advances. Sustainability adoptions face significant resistance from different cultures that prevent their implementation. The combination of traditional business operations together with the widespread technological mistrust creates obstacles to widespread adoption. AI-driven solution acceptance requires trust-building efforts as well as organizational innovation culture development to surpass these social obstacles (Iyelolu et al. 2024). Firms are also facing issues regarding data privacy and cyber crimes such as companies making AI implementations. Another barrier lies in financing and knowledge spreads.

Sustainable Development in the Context of the Middle Eastern Context

The special economic structure combined with the environmental situation of the Middle East requires both implementation and technical challenges with sustainable technologies powered by artificial intelligence systems. Old economic and political systems in the region formed through hydrocarbon revenue dependence now need substantial transformation to implement cleaner sustainable practices. The national visions of Saudi Arabia's Vision 2030 and the UAE's Green Agenda 2030 demonstrate a leading political commitment to support sustainable innovation (Islam & Ali, 2024). The initiatives work toward economic diversification while reducing carbon pollution to make Middle Eastern countries leading global examples of sustainable development.

Location elements increase the urgency to adopt sustainable technologies in this region. The region faces three fundamental sustainability issues involving scarce water availability along with harsh environmental temperatures and environmental deterioration which require groundbreaking solutions. Through water resource optimization and precision farming improvements, AI can help resolve

environmental problems. In addition to that, it has identified that the adoption of green innovation that is through AI "artificial intelligence" has also encounters several barriers particularly within its transformation path. The political landscape that is mainly across the area has further demonstrates diverse stabilities mainly due to certain countries have encounter other barriers while implementing any particular reforms. Society also combines a number of perspectives that is associated with the technological adoption as several traditional customs and many doubting attitudes that are specifically towards AI further create obstacles totally against change.

5 Discussion

Both Shot as well as long-term investments that are mainly for sustainable projects and also alongside AI-powered green innovations have been the key source that have prove almost difficult to appropriately secure even a financial backing that is even since numerous economies. It further establishes their overall priorities directly from short-term profits above long-term sustainability goals and aims. Insufficient availability of any green financing may also further hinders the launch as well as deployment of numerous sustainable technology systems (Bianchi & Putro, 2024). In addition to that, from the above result it can be accurately considered that achieving local capacity development and also aquiring sustained creation of policy framework while encouraging sector-wide collaboration has also becomes essential for the primary integration of Artificial Intelligence into multiple sustainable development solutions. The growing dedication of the region that is to sustainability is further reflected through this national movement and it is also while demonstrating a wider acceptance of economic strength and resilience construction.

Artificial Intelligence-driven green innovation has further leads this regional development because it brings sustainable pathways to any developments which are almost consistent with numerous global trends and positions within the Middle East as a significant and even more advanced leader in multiple climate challenge solutions. The result also mentioned that different governments throughout the region steadily increase their investments to digitize operations as they build out their sustainability goals (Islam & Ali, 2024). The Saudi Arabian leadership established Vision 2030 as a strategy which embraces renewable energy together with smart cities and AI applications to make energy divisions sustainable while developing agriculture and water management systems. The UAE utilizes both the Green

Agenda 2030 and the National AI Strategy to facilitate AI integration across environmental surveillance and waste management along with energy optimization because they seek to use technology for sustainable development.

6 Conclusions

Websites show that artificial intelligence speeds up ESG-driven green innovation through better decision-making methods and improved energy efficiency and environmental problem solutions. Still there exist obstacles including incomplete policies and cultural opposition and unprepared technology which must receive attention. The research verifies that AI integration within ESG initiatives speeds up the development of green innovative approaches. The study proves that proper regulation and training programs enable AI technologies to promote sustainable technological advancements within the area. The study uses qualitative methods combined with a case study which restricts the wide applicability of its results.

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Polish Agriculture on the Road to Sustainable Agriculture

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European Union (EU) agriculture produces food in sufficient quantity and quality, ensuring food security for EU citizens. Financial support mechanisms under the Common Agricultural Policy (CAP) guarantee affordability for consumers and decent incomes for farmers. In 2019. The European Green Deal (EGD) emphasized the importance of agriculture in climate protection. It set a new direction for change, putting EU farms at the center of sustainable food production. All this meant that existing agricultural practices in the EU allowed for high productivity, but also gave space for sustainable practices. The new financial support mechanisms under the CAP for 2023-2027 have focused on financing agricultural practices that protect the environment. The main purpose of the article is to discuss the future directions of agriculture in EU countries. Based on data on the agricultural sector in Poland, it is shown that an important direction of agricultural development is the digitization of farms and villages, which is a prerequisite for the introduction of precision farming practices. On the one hand, this allows to increase yields and reduce the consumption of natural resources, and in the long run increases productivity in agriculture. On the other hand, it facilitates the implementation of ESG reporting.

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1 Introduction

EU farm practices ensure the food security of its citizens and the high position of EU agricultural products in the world (Knudsen, A.S.L., 2011). However, the observed global climate change, environmental degradation and loss of biodiversity are shedding new light on the actions taken by international institutions (EC., 2019a; UN., 2015), which are now prioritizing sustainable practices. The idea of sustainable agriculture is not a new concept in agricultural economics. However, acceptance of the fact that natural resources used for food production are limited now requires more focus. In EU countries, agricultural productivity has been achieved through intensive agriculture practices. Mechanization, digitization, intensive use of chemical fertilizers and pesticides have allowed the EU agricultural sector to achieve high productivity and reduce farmers' labor input, unfortunately at the expense of environmental degradation and structural changes in rural areas.

However, a shift away from intensive agricultural practices seems neither possible nor justified. Intensive agriculture in the EU is essential to ensure food security for EU citizens and a growing global population. Breaking up monocultures may have a regenerative effect on the environment, but it also risks the loss of economic advantage for EU farms in growing crops and breeding animals. There is evidence in the academic literature that downsizing is technically and economically effective only on small-scale farms (Rada, N.E., & Fuglie, K.O., 2019). In light of these facts, the preferred course of action should not be to move away from intensive agriculture altogether, but rather to replace intensive agriculture practices with sustainable and precise practices (Wrzaszcz, 2023).

Precision agriculture is a farm management concept that uses digital technologies to monitor crops and animal breeding and optimize agricultural production decisions (Monteiro, A., Santos, S., & Gonçalves, P., 2021). Smart agriculture solutions are having a significant positive impact on agriculture practices in every type of operation and at every scale of production. The introduction of advanced information technology and artificial intelligence alone provides the precision to achieve higher yields, both in terms of quantity and quality and reduces the burden on nature and the climate (Sharma, S., Verma, K., & Hardaha, P., 2023). Automated control systems, data-driven fertilization and crop protection systems, field robots, drones, soil analysis sensors, and automatic process control are optimizing

agricultural production in technical, allocative, economic, but also, importantly, environmental terms. Precision agriculture is changing the living conditions in rural areas, changing the demand for farm labor in terms of quantity and quality, as well as new skills for farm workers (technical and environmental skills).

In addition, precise crop and livestock monitoring tools are an important component of the (future) reporting system under design (Burnaev, E., Mironov, E., Shpilman, A., Mironenko, M., & Katalevsky, D., 2023). This is because it is assumed that through a combination of technical equipment, innovations in the agricultural sector, information and communication technologies, sustainable practices in crop and livestock breeding will be possible, while at the same time the conditions will be created for obtaining the data necessary for ESG reporting on each farm, i.e. the environmental, social and governance impacts of agricultural activities.

The main purpose of the article is to discuss the future directions of agricultural development in European Union countries. Precision agriculture should hold a key place in this discussion among farmers, politicians and academics, as it represents the only way to achieve food security for the citizens of the European Union and the growing global population, and also provides opportunities to achieve the Sustainable Development Goals and the European Green Deal. The digitization of agricultural operations, in the implementation of IT and AI systems on more farms, is seen as an opportunity to reduce their negative impact on the environment, climate and society. The situation in the Polish agricultural sector in Poland provides the background for a discussion on the spread of precision agriculture practices.

The content of the article is presented in the following sections of the article according to the following order. The discussion begins with a section describing the essence of precision agriculture and its development in European Union countries. In the third part, the importance of precision agriculture for the implementation of the goals of the European Green Deal is presented, and the anticipated mechanisms of financial support for farms within the framework of the Common Agricultural Policy for 2023-2027 are described. In the fourth part, the usefulness of using precision methods in ESG reporting of farm activities is signaled. In the last – a discussion of the situation of agriculture in Poland is presented, taking into account the status of implementation of precision agriculture practices on the

way to achieving climate goals. The discussion ends with generalized remarks in the conclusion.

2 Precision agriculture in European Union

Precision agriculture responds to the contemporary need to implement technical progress in the European Union's agricultural sector, although like any change it raises objections, both among farms primarily for technical and economic reasons, and among food consumers, among others, regarding the introduction of new genomic techniques (NGT) into crops. These concerns, while unfounded, are a significant obstacle to its development. Farmers, despite the knowledge that precision agriculture saves on the use of natural resources, material resources and labor, and that it maximizes production and consequently improves crop and livestock productivity, note the technical difficulties associated with its introduction and the problem of financing capital expenditures. At the center of precision agriculture are IT and AI technologies that communicate with each other and with the farmer. With the assistance of sensors, drones and systems, application maps are created that are able to design crops, and real-time monitoring with them, from the app's position, observes and responds flexibly to environmental risks (Chin, R., Catal, C., & Kassahun, A., 2023). "From the field" data on soil moisture or plant condition, among other things, assists in taking action on irrigation methods or nutrient application methods that ensure farms achieve maximum yields. Similarly, precision livestock breeding methods, i.e. cow ear tags, automated milking systems, automated feed wagons reduce ongoing production costs and allow farmers to achieve higher levels of competitiveness (Martin, T., et al., 2021). Information technology and artificial intelligence in the long term should provide data to facilitate planning, dispatching and recording of activities, creation of templates to facilitate record maintenance, including but not limited to "from the field" documentation, nutrient balancing and optimization of the economic account at the farm level. A major problem for farms in the EU today is the financing of capital expenditures associated with the transition to precision practices.

The implementation of precision agriculture directly affects the economic benefits achieved by farms, allows to customize agricultural treatments for individual plants and animals, reduces production costs. However, the benefits of precision agriculture go beyond economics – precision agriculture reduces, as it reduces the

negative impact of agricultural production on the environment. In 2019 European Green Deal – EDG (EC., 2019a) assigned the agricultural sector a role in achieving EU climate neutrality, pointing out that this can be achieved by, among other things, changing food production practices and delivery methods, and protecting biodiversity on agricultural land. According to an analysis by the European Environment Agency (EEA, 2024), the agricultural sector accounts for 11% of the EU's greenhouse gas emissions, so changing agricultural production techniques to precise ones is key to reducing them.

3 European green deal and common agricultural policy in the implementation of precision agriculture

The European Green Deal is a strategy that is a commitment by the European Union to take responsibility for transforming the EU economy into a modern, resource-efficient and competitive economy, achieving zero net greenhouse gas emissions and whose economic growth is decoupled from the use of natural resources (Arabadjieva, K., & Bogojević, S., 2024). The implementation of the EGD for agricultural activities and the related A Farm to Fork Strategy (EC., 2020) and the EU Biodiversity Strategy for 2030 (EC., 2020a) obliges each EU country to prepare a national long-term strategy for climate neutrality – a long-term strategy (EC., 2019). One of its fields in this regard is defining a plan for, among other things, reducing greenhouse gases from the agricultural sector, reducing the use of chemical fertilizers and synthetic pesticides, restoring natural ecosystems and how to achieve them. The way to achieve the country's long-term strategy is through, among other things, the development of sustainable agricultural practices, such as precision agriculture or organic agriculture, as well as the protection of biodiversity. Agricultural activity has always been linked to respect for natural resources, but now the EGD has set measurable tasks for EU agricultural sectors in relation to climate and environmental goals. The need to take climate and environmental aspects into account has led to new mechanisms for financial support of farms under the Common Agricultural Policy (CAP). Under the 2023-2027 CAP (European Parliament, 2021), 40% of the budget has been allocated to financial support for farms that meet climate goals. The revised financial support mechanisms have also been linked to the promotion of other farm ecosystem services (de Groot et al., 2022). Among the important changes in the 2023-2027 CAP are increased spending on climate, environment and animal welfare, as well as the implementation of a new type of payment known as

ecoschemes. Financial support now includes: modernization of farms, e.g., precision agriculture solutions in buildings and structures for animal breeding, crop production activities, e.g., purchase (leasing) of harvesting machinery, other investment expenditures, especially expenditures for improving product quality, innovation, changing the profile of activities. Also noteworthy is the change in approach to financial support for small and medium-sized farms. All the measures taken are aimed at maintaining food security in the EU and the world and achieving EU climate neutrality. Each EU country is required to submit a customized Strategic Plan for its agriculture, in which it indicates concretized goals related to the directions of transformation of agricultural production in connection with the achievement of climate neutrality, along with the possibilities of financial support for the planned activities (interventions).

Farms in the EU, especially those engaged in intensive agriculture, are recognizing the benefits of adapting precision agriculture solutions, and customized financial support mechanisms under the CAP are a big incentive to adopt them. However, IT and AI technologies require access to appropriate infrastructure, as well as investment in fixed assets.

The full implementation of the idea of precision agriculture requires the collection and analysis of digital data, which in the long run is expected to allow the creation of a virtual space that is a platform for the exchange of experiences and agricultural practices - economically and environmentally efficient. IT and AI technologies in the long run should provide data to facilitate planning, dispatching and recording of activities, creation of templates to facilitate record-keeping, including "from the field," "from the barn" documentation, balancing nutrients and optimizing the economic calculation, both at the micro and cross-local levels. On the other hand, at the institutional level, precision agriculture will provide rapid control and adjustment of financial support mechanisms, quotas and contracts, enabling greater transparency and facilitating compliance.

Data obtained from precision machines can also be useful for implementing non-financial ESG reporting in agriculture.

4 ESG reporting in the EU agricultural sector

The European Union's climate policy formulated in the European Green Deal is being implemented rapidly, and one of its manifestations is ESG reporting.

In 2024, the NFRD (European Parliament and of the Council, 2014) was replaced by the CSRD (European Parliament and of the Council, 2022), as a result of which non-financial reporting was replaced by ESG reporting. The main purpose of non-financial reporting was to meet investors' needs for information on non-financial factors that could influence effective decision-making in the long term. ESG reporting under CSRD aims to report on corporate sustainability issues that address environmental, social and corporate governance issues, providing greater transparency in this regard. In ESG reports, entities show how they manage risks and evaluate their strategy.

Although the implementation of mandatory ESG reporting stems from the EU CSRD, the implementation schedule is being developed individually by each member country, so the implementation of ESG reporting is not uniform. There are countries in the EU where the implementation of reporting has begun, such as Finland, Slovakia and the Czech Republic, and countries where the implementation schedule process is in the consultation phase, such as Croatia and the Netherlands.

The European Commission has approved the Sustainability Reporting Standards – ESRS (EC., 2023). The standards require a companies to use a value chain approach when disclosing ESG data. If access to information at certain stages of the value chain is difficult, companies are required to disclose this in the report, explaining the steps taken to access the required information. In this way, companies provide accurate information about their entire environmental and social impact.

Agriculture, i.e., farms, is currently not directly covered by ESG reporting, although there are plans for its gradual inclusion. Nevertheless, ESG reporting indirectly supports agriculture's transformation to sustainable agriculture. ESG reporting standards require covered companies to audit their entire supply chain. Therefore, companies that care about reducing the CO_2 footprint of their operations are not indifferent to the carbon footprint of even single, small-scale suppliers, i.e. farms. What's more, these companies can benefit from the potential of sustainable farms,

e.g. small-scale organic farms, or farms using precision agriculture practices by deducting CO_2 from their carbon footprint. Regardless of whether or not farms are directly covered by ESG reporting, they must comply with ESG reporting requirements if they want to work with large companies in the long run. The reality is that companies will not be able to work with those farms that are unable to demonstrate their carbon footprint.

5 Polish agriculture on the road to sustainable agriculture

The European Green Deal has set specific, quantitative goals for the agricultural sector. By 2030, it is to reduce the use of plant protection products by 50% and mineral fertilizers by 20%, allocate a minimum of 10% of arable land to pro-environmental purposes and a minimum of 25% of agricultural land to organic agriculture. Achieving these ambitious goals depends on the commitment of the country's agricultural sectors.

Polish agriculture currently has a significant position in the EU agricultural sector. According to the Central Statistical Office (2024), in 2022 it ranked 5th in the European Union in terms of agricultural production value, was the largest producer of apples in the EU, ranked 3rd in wheat production and 2nd in rye production, 3rd in milk production and 4th in pork production. At the same time, it is characterized by a large number of small farms, mainly family farms. In addition, a feature of Polish agriculture is the small share of organic crops, much lower than the average for EU agriculture. 3.45% of the cultivated area in Poland is organic, with an average of 9.10% of the organic area in the European Union (Central Statistical Office, 2024).

The position of Polish agriculture has been achieved through consistent efforts to increase the scale of operations and intensify production, but the potential of Polish agriculture is still not used – farms in Poland still need to increase investment, increase innovation. The established goals of the European Green Deal have set new paths of development, in particular, the change towards precision agriculture.

Poland, similar to other EU countries, has included modernization, increased innovation and digitization of farms and rural areas in the CAP Strategic Plan for 2023-2027, and proposed forms of financial support for related investments. The Strategic Plan emphasizes that the development of digitization of farms and rural

areas is a prerequisite for the use of precision solutions, increasing the importance of technology in agricultural production.

The main challenges of digitization of farms and rural areas in Poland include:

- support for the development and modernization of IT infrastructure in rural areas,
- bridging territorial disparities in Internet access between rural and urban areas,
- modernization of farms in particular in the field of automation and digitization of production,
- creation and implementation of innovative applications and open IT platforms through which remote consulting is possible,
- digitization in the implementation of agricultural policy instruments facilitating the development and dissemination of tools for optimization of agricultural production processes,
- improvement of digital, market and technological competence of farmers and rural residents (Plan, 2023).

Interventions to support precision agriculture solutions envisioned in the CAP Strategic Plan 2023-2027 include financial support to farms for investments that increase their competitiveness, investments that improve the welfare of cattle and pigs, investments that contribute to environmental and climate protection, sector interventions – fruits and vegetables. In addition, it was highlighted that an important group of activities planned for support are investments in rural infrastructure and the implementation of the smart village concept. The CAP Strategic Plan 2023-2027 also includes a plan for financial support within the framework of cooperation of EPI Operational Groups and activities referred to as the "Leader" program. Supported activities are implemented in four areas (from A to D).

Examples of activities covered by financial support for Polish farms within the framework of the presented CAP Strategic Plan 2023-2027 are realized investments in navigation systems for tractors and agricultural machinery, systems for increasing the precision of machine guidance, systems for controlling the dosage of fertilizers,

plant protection products, seed, feed, antibiotics, water necessary for production, feed robots, feed tapping devices, yield mapping systems, telemetry systems, decision support systems, robots and autonomous systems, e.g. robots for strawberry harvesting, robots for recognizing and eradicating weeds, walking fencing system in pastures, automated animal selection and weighing systems, cleaning robots.

In providing support under each area, it was assumed that the main result of the activities planned for funding is the digitization of farms and rural areas, so the main criterion for selecting supported activities is investment in digital solutions, regardless of the areas of intervention. As a result, there has been significant digitization of Polish farms and rural areas. In 2023, the Internet in Poland was available to an average of 85.32% of people using it regularly, an increase of 3.96% compared to 2020 and an increase of as much as 25.45% compared to 2013. People living in cities and urban areas compared to those living in rural areas use the Internet more regularly. Internet access in rural areas may be an obstacle to the full implementation of precision agriculture. In Poland, as in the rest of the EU, the development of digital infrastructure is supported by the European Funds Program for Digital Development, the National Plan for Rebuilding and Increasing Resilience and national funds. In addition, the development of digitization in the agricultural sector is funded under Horizon 2020, Horizon Europe or the Digital Europe program. The measures finance extensive investments related to financial outlays for providing Internet access, eliminating so-called "white spots", i.e. digitally excluded regions, implementing satellite monitoring systems and developing maps of agricultural areas. The aim of all the measures covered by the financial support is to increase the economic efficiency of agricultural production and reduce the negative impact of agricultural production on the environment, optimize the use of natural resources, which should bring the EU agricultural sector closer to achieving the set goals of the European Green Deal.

6 Conclusions

The European Green Deal has set a path for the European Union's agricultural development, which includes increasing resource efficiency, improving the competitiveness of production and reducing its negative impact on the environment. Precision agriculture is one of the key tenets of this development. The article examines the essence of precision agriculture and identifies its key elements – from

monitoring and data collection systems to decision support tools and automated application technologies. Attention was paid to the diversity of applied solutions, such as satellite technologies, soil sensors, drones, GPS systems or yield mapping, which enable production to be carried out in a more precise and cost-effective manner. As a result, it is assumed that a digital platform will be created to promote good practices among users of agricultural technologies. The platform should also be a valuable tool for designing future Common Agricultural Policy programs and ESG reporting.

The purpose of the article was to discuss the future directions of of agricultural development in European Union countries. Precision agriculture currently occupies a key place in the discussion of the implementation of the sustainable development goals of the Sustainable Development Goals and the European Green Deal. It is seen as an opportunity to simultaneously increase the efficiency of agricultural operations and reduce their negative environmental, climate and social impacts. Precision agriculture allows the acquisition of new data that can reveal the impact of agricultural activities on the environment, society and governance. The development of precision agriculture is of particular importance due to the need to balance agricultural production practices with modern technologies and the need to adapt agricultural activities to the requirements of the European Green Deal and EU climate policy. There is growing interest among farms in implementing precision agriculture practices.

The results of the analysis carried out in the Polish agricultural sector provide a basis for further research on precision agriculture practices, which should focus, on the one hand, on comparing the costs and benefits (economic and environmental) of implementing digital technologies in the agricultural sector, analyzing the return on investment in precision agriculture, and, on the other hand, learning about the level of preparedness of farms to meet future requirements for reporting the environmental, social and corporate governance impacts of agricultural activities – ESG reporting.

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Comparative Analysis of the Role of Gender Equality in Environmental, Social, and Governance Performance Across Belgium, Denmark, Luxembourg, and Hungary

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This paper examines the impact of gender equality on the Environmental, Social, and Governance (ESG) performance of Belgium, Denmark, Luxembourg, and Hungary, focusing on the proportion of women in leadership positions. Utilizing a comparative, index-based approach, the research evaluates data from 2011 to 2021 using indicators such as the Sustainable Development Goals (SDG5), Human Development Index (HDI), and Social Progress Index (SPI). Findings reveal that Belgium and Denmark exhibit the highest gender equality progress in leadership, while Hungary lags despite minor improvements. Contradictions between national and European statistical data highlight discrepancies in reporting methodologies, particularly regarding the public and private sectors. The paper examines the correlation between higher female representation in leadership and improved ESG performance, suggesting that increased gender diversity contributes to corporate sustainability. Research limitations include data inconsistencies across statistical sources and the exclusion of sector-specific analyses. The findings provide valuable insights for policymakers and corporate governance stakeholders, reinforcing the necessity of achieving the EU-mandated 40% female leadership quota by 2026. The paper's originality lies in its comprehensive, multi-index evaluation, offering a nuanced perspective on gender equality's role in ESG performance within the examined European countries.

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1 Introduction

Gender equality, particularly the representation of women in leadership positions, remains a critical issue in the 21st century (UN Women, 2023). Despite numerous advancements, women still hold only 31.5% of leadership positions globally as of 2022, with even lower figures in Hungary (9,4%), where the share of women in leadership remains below the European Union (abbreviation: EU-27) average. In response to these imbalances, the EU-27 has implemented several policies to promote gender equality, including the Gender Equality Strategy (2020-2025) and the "Women on Boards" Directive. The latter mandates that by 2026, listed companies must ensure that at least 40% of their board members are women (European Counsil, 2025).

Systemic barriers, such as the "glass ceiling" phenomenon, continue to hinder women's career advancement (Nagy Beáta, 2005; Ryan & Haslam, 2005).

While progress has been made—demonstrated by the increasing presence of women in executive roles—female leadership remains the exception rather than the norm. Some countries have implemented policies, such as quota systems, to accelerate progress, while environmental-social-governance (abbreviation: ESG) criteria now require corporations to report on gender equality metrics (Galsanjigmed & Sekiguchi, 2023; Pounder et al., 2023). Given these ongoing challenges, it is essential to analyse how different countries perform in terms of gender equality, particularly in leadership positions (Galsanjigmed & Sekiguchi, 2023; Pounder et al., 2023). This paper compares Hungary, Belgium, Denmark, and Luxembourg, examining gender representation in leadership within the broader context of corporate competitiveness and environmental performance. The selected countries exhibit diverse economic structures, corporate governance frameworks, and varying degrees of gender equality in leadership positions. Belgium, Denmark, and Luxembourg exemplify economies with robust ESG commitments and relatively high female representation in leadership roles, which provides a valuable contrast to Hungary's lower gender diversity at the top (Eurostat, 2024; Tyrowicz et al., 2020).

This comparative analysis enables a deeper exploration of the interplay between corporate competitiveness, environmental performance, and gender equality across different European settings. By evaluating these factors, the research aims to assess whether Hungary's low proportion of female leaders constitutes an anomaly or aligns with broader patterns across EU member states.

2 Literature review

The notion of the necessity for women's representation in positions of leadership has been repeatedly questioned. Often posed by men, this inquiry reflects a persistent scepticism regarding gender diversity in corporate governance (Galsanjigmed & Sekiguchi, 2023; Pounder et al., 2023). The response, supported by empirical evidence, is clear: gender diversity in leadership is economically advantageous. From a business perspective, gender diversity in leadership is a financially sound decision that aligns with the principle of double materiality, encompassing both financial and ESG considerations (Girardone et al., 2021). Empirical research has shown a positive correlation between gender diversity in leadership and stronger organisational performance (Hunt et al., 2018; Mothe & Nguyen-Thi, 2021; Tenner & Hörisch, 2021). Companies with greater female representation in executive roles often achieve better financial outcomes, highlighting the broader economic benefits of inclusivity (Galsanjigmed & Sekiguchi, 2023; Hunt et al., 2018; Portfolio, 2023). Beyond financial success, gender diversity plays a crucial role in cultivating a more balanced, inclusive, and equitable corporate culture, with far-reaching implications for governance and broader strategic (Hunt et al., 2018). Research has shown that there are cognitive differences between men and women, which, while not inherently superior or inferior, can significantly influence leadership dynamics and organisational behaviour (Ágnes Valló et al., 2002). According to Ágnes Valló et al. (2002), women may more frequently engage cognitive processes associated with creativity and integrative thinking, which can contribute to more open-minded and innovative approaches to problem-solving. (Ágnes Valló et al., 2002)This cognitive trait fosters a willingness to consider diverse perspectives and alternative viewpoints, which is essential in today's complex business landscape. Furthermore, these characteristics contribute to improved decision-making, better negotiation outcomes, and overall corporate adaptability (Ágnes Valló et al., 2002). Such attributes are invaluable in navigating

the challenges of an increasingly interconnected global economy, reinforcing the idea that gender diversity brings a broad range of benefits to organisations across various sectors (Ágnes Valló et al., 2002). Gender-balanced leadership offers consumer-oriented advantages, including better market understanding and customer engagement. Women comprise a significant proportion of global consumers, so businesses that integrate female perspectives can better meet diverse needs, leading to increased sales and brand loyalty (Hunt et al., 2018). Gender diversity in leadership is also a strategic investment that signals corporate commitment to equity, enhancing brand image and reputation. Moreover, gender-balanced leadership inspires future generations of aspiring female professionals, helping to dismantle societal biases and foster an inclusive professional landscape (Hunt et al., 2018). Despite ongoing challenges, this paper examines how gender diversity in corporate leadership has evolved across select EU-27 member states, including Denmark, Belgium, Luxembourg, and Hungary. By analysing cross-national trends and policy frameworks, the research aims to identify factors influencing gender equity and best practices for fostering a more inclusive corporate environment. Understanding these regional variations can inform broader discussions on the efficacy of gender diversity policies and pathways toward greater representation of women in leadership.

3 Methodology

This paper examines gender equality, focusing on the representation of women in leadership roles, by comparing Belgium, Denmark, Luxembourg, and Hungary from 2011 to 2021. Various data sources and measures are used to understand and compare the proportion of women in leadership positions in these countries, as well as the factors affecting this representation. The following describes the data collection, processing, and analysis methods employed.

3.1 Data Collection, Processing, and Comparison

The primary data sources for this research were the EUROSTAT and the Hungarian Central Statistical Office databases. Data for the years 2011 to 2021 served as the foundation of the paper, as these years provided the most comprehensive and reliable information regarding progress on gender equality in leadership roles.

3.1.1 Eurostat Data

The Eurostat database contains data on the representation of women in leadership positions across different countries. Analysis of the data from 2011 to 2021 for Belgium, Denmark, Luxembourg, and Hungary revealed varying trends:

- Belgium and Luxembourg experienced continuous but varying rates of increase in the representation of women in leadership roles, while Denmark saw a significant rise in 2017, followed by a subsequent decline.
- In Hungary, stagnation and even a decrease were observed, highlighting concerns about gender equality in leadership positions.

Data for these countries were downloaded from the Eurostat database, and a comparison of the proportion of women in leadership roles was made across these nations.

3.1.2 KSH Data

According to data from the Hungarian Central Statistical Office, the percentage of women in leadership roles within the ISCO-1 major occupational group in Hungary rose to 36.6% in 2021. In contrast, EU-27 data showed a decrease to 9.4%. This difference is due to the varying representation of women in leadership positions between the public and private sectors, with more women in leadership roles in the public sector compared to the private sector.

3.1.3 Indices Data

Three key indices were utilized in this research to measure gender equality and socio-economic development: Sustainable Development Goals (abbreviation: SDG) index, Human Development Index (abbreviation: HDI), Social Progress Index (abbreviation: SPI). These indices provided a more objective understanding of the socio-economic development of the countries studied and their correlation with progress in gender equality.

3.2 Standardiastion and Analytical Methods

The first step involves standardising the baseline data with various units and dimensions into a common metric scale, following the methods described by Belak & Nedelko, 2024; Macher et al., 2023; Macher & Szigeti, 2024; Szabó et al., 2023.

The next step is to define a benchmark, where the values of EU-27 Member States are compared to the maximum value in the set. This is followed by calculating the Euclidean distance, which shows how far the indicators are from a specific reference point. Finally, an integrated index with uniform dimensions is computed for a three-axis matrix analysis. This novel integration of benchmarking with Euclidean distance and matrix-based index construction offers a unique methodological framework for cross-country comparison, which has not yet been widely applied in the context of gender equality in leadership roles.

4 Results

From 2011 to 2021, women's representation in EU-27 leadership roles fluctuated, averaging 33.09%. The percentage initially declined to 32% before recovering to 35% by the end. These variations suggest uneven progress in gender equality, reflecting ongoing challenges women face in leadership. The data reveals significant differences in gender equality progress across EU-27. In 2011, Norway, Latvia, and Finland had the highest representation, later joined by Iceland and France. Among the countries analysed, some showed mixed progress, while Hungary consistently ranked near the bottom. These findings highlight the divergent trajectories of gender equality in the EU-27, with some countries advancing substantially while others saw little improvement. A comparative analysis using international gender equality indices, such as the SDG index, HDI, and SPI, provides further context for these trends. Standardising these indices and calculating Euclidean distances reveals significant differences between the selected countries over time (Figure 1.).

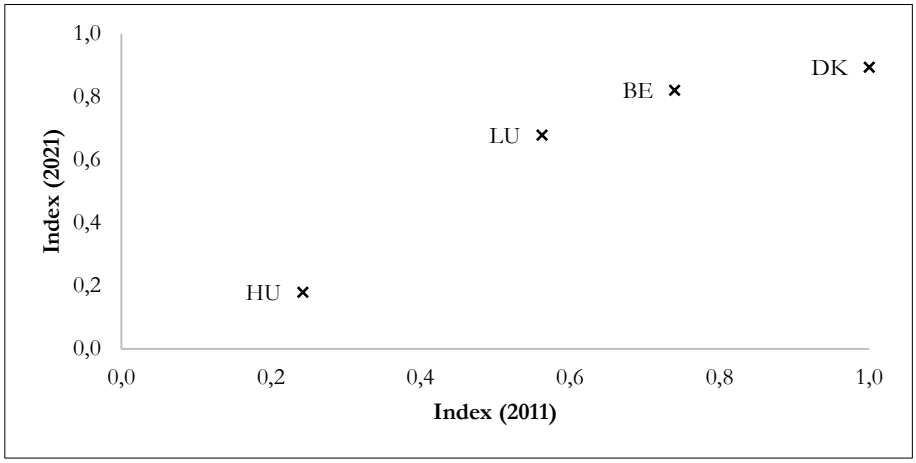

Figure 1: Index-based comparative analysis of the countries examined

The results show that Luxembourg had the largest positive shift, with a 20.6% increase in the proportion of women in leadership positions. Belgium also improved, with a 10.92% rise. In contrast, Denmark, despite initially leading in gender equality, experienced a 10.65% decline. The most pronounced negative trend was in Hungary, where the proportion of female leaders decreased by 25.88% over the decade.

5 Discussion

The analysis of index-based metrics indicates positive developments in gender equality from 2011 to 2021, particularly in the representation of women in leadership positions. Belgium and Luxembourg demonstrated the most substantial improvements. While the proportion of women in leadership roles increased across the four nations, women continue to be an underrepresented group, especially in senior-level positions (Központi Statisztikai Hivatal, 2022). Overall, the EU-27 experienced an upward trend in female leadership representation, with Denmark and Belgium exhibiting the most significant (Eurostat, 2024). Belgium's female leadership proportion rose remarkably from 10.9 % to 37.9 %, the highest among the countries studied. Luxembourg quadrupled its female leadership representation from 5.60 % to 22.4 %, and Hungary also showed progress, albeit at a slower pace, from 5.30 % to 9.40 %. The EU-27 countries exhibited varying rates of growth in female leadership representation over time. While Belgium and Denmark emerged

as top performers, achieving higher percentages of women in leadership roles, this was not universally accompanied by stronger economic growth across the region (Social Progress Imperative, 2024). The data revealed an inverse correlation between female leadership rates and overall growth rates. Luxembourg and Hungary made some progress but lagged their peers in advancing gender equality at top leadership levels. The path to parity remains uneven, underscoring the need for sustained efforts to promote women's advancement and leadership opportunities across the EU-27 (Bodnár Éva & Sass Judit, 2024; European Institute for Gender Equality, 2017; Hunt et al., 2018). Gender equality varied among these states but generally improved over time. The EU-27 aims for 40% women in leadership roles at publicly listed companies by 2026. Progress toward full equality remains slow, though Belgium and Denmark have succeeded in increasing female representation in leadership. Achieving complete gender equality will be a gradual process across the EU-27. Promoting gender equality is vital for social justice, economic progress, and environmental stewardship.

6 Conclusions

The paper examines the progress of gender equality in leadership roles across the nations studied from 2011 to 2021. The findings show a generally positive but gradual trend, particularly in Belgium, Denmark, and Luxembourg. These countries saw significant growth in women's representation in managerial positions, with Belgium having the largest increase among the examined states. However, women remain underrepresented in top-level leadership roles, especially in Hungary, where the growth has been slower. At the EU-27 level, the data indicates a consistent rise in women's representation in leadership, though the pace has varied. The EU-27's ongoing initiatives, including legal actions to increase the proportion of female executives in publicly traded companies, demonstrate its commitment to promoting gender parity. Yet, achieving full gender equality in leadership remains a major challenge, as many EU-27 Member States continue to see slow progress in this area. In conclusion, the data shows a gradual yet positive trend toward greater gender parity in leadership positions across the examined nations. While progress has been made, the journey to full gender representation in senior roles is ongoing. Continued advocacy for gender equality is crucial not only for advancing social justice but also for driving economic and environmental progress, ultimately benefiting societies.

The experiences of countries like Belgium and Denmark serve as examples of what can be achieved through persistent efforts and effective policies.

The research presented in this paper holds significant practical and theoretical importance for Hungary and the EU-27. It draws the attention of researchers and EU decision-makers to the fact that EU-27 statistical data primarily focuses on the private sector, neglecting the public sector and the unique data collection methodologies employed by individual member states. Consequently, the public sector is excluded from evaluations, which can distort data quality. However, these two domains should be examined in a joint context. For the specific case of Hungary, the research serves as a signal to not limit the focus solely to the public sector, but to also include the private sector, where the proportion of women in leadership positions is notably lower. This, in turn, highlights the need for greater intervention by companies. Furthermore, the findings can guide HR and other social fields, demonstrating how "best practices" from the public sector can be adapted to the private sector, potentially through country-specific support measures. This holistic approach enhances the understanding of the societal issue at hand. The research also holds value for international scholars, as it can help them avoid data interpretation errors by emphasising the importance of attending to data collection methodologies, preventing misleading conclusions. In summary, this study underscores the need for more comprehensive data provision. The joint examination of the two sectors represents an under-researched area, which can initiate a new research direction focused on gender equality and the proportion of women in leadership positions.

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CYBERSECURITY IN E-BANKING

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This study aims to analyze the challenges and defenses in e-banking cybersecurity. The main goal is to identify the most common threats, the factors that affect the success of attacks and the effectiveness of defenses implemented by financial institutions. This study is important for financial institutions and e-banking users, as it helps to raise awareness and develop better strategies for protecting financial data. To achieve this goal, a qualitative methodology was used with a purposeful selection of participants, including cybersecurity experts and representatives of the banking sector. The main data collection instruments were semi-structured interviews and literature review, providing a complete overview of the risks and defense strategies adopted. The findings have shown that phishing attacks, malware, DDoS and insider attacks are among the main threats facing e-banking systems. Technological measures, such as multi-factor authentication and real-time monitoring, have been identified as key strategies for protecting systems. Likewise, customer education and employee training are critical factors in minimizing risks. Improving IT infrastructure and adopting advanced technologies, such as artificial intelligence and block chain, are recommended to strengthen security in the global banking sector.

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1 Introduction

Cybersecurity in e-banking is one of the main concerns in the modern world of financial technology. With the significant increase in the use of electronic banking services, cyber threats and attacks have become increasingly complex, putting the security of users' financial and private data at risk. Banks and financial institutions are facing major challenges in securing their systems and protecting customers from potential financial losses and reputational damage.

Security requirements for e-banking systems include the use of advanced authentication mechanisms, data encryption, and the application of ongoing risk management strategies. According to researchers such as Anderson (2020) and Schneier (2019), one of the main factors influencing the increase in cyber threats is the evolution of technologies and the lack of user awareness of potential risks. This has created an important space for in-depth research regarding measures that can be taken to improve cybersecurity in banking systems.

The study of cybersecurity in e-banking is of great importance for many reasons. First, it aims to identify the main threats and challenges facing these systems, providing a solid basis for further improvements. Second, it helps raise awareness among users and financial institutions about the importance of sophisticated protective measures. Moreover, effective cybersecurity positively impacts customer confidence and maintains the stability of the banking sector.

This study aims to investigate and analyze the challenges and protective measures in cybersecurity for e-banking, helping to develop effective strategies to reduce risk and improve the protection of user data. The main questions of this research include:

- What are the main cyber threats affecting e-banking?
- What factors influence the spread and success of cyber attacks in this area?
- What protective measures can be applied to reduce these threats?

Based on current literature and practice, this study will provide a clear overview of the current state of security in e-banking and opportunities for sustainable improvements.

2 Literature review

This section analyzes three main issues: the main cyber threats facing these systems, the factors that influence the spread and success of these threats, and the protective measures that can be applied to reduce the risks. The analysis is based on extensive studies of scientific and practical literature, including diverse experiences from different sectors of global banking.

E-banking systems are prime targets for cyber criminals due to the direct involvement of money and sensitive data. Among the most common threats are:

1. *Phishing Attacks:* Phishing is a major threat in e-banking systems, where users are tricked into providing their personal information through fake emails or websites. Kay et al. (2021) emphasize that these attacks have been highly successful due to the human factor and lack of awareness. Furthermore, Chanti and Chithralekha (2022) report that phishing attacks are constantly evolving, using more sophisticated techniques to deceive victims.
2. *Specialized Malware:* Malware, such as banking Trojans and ransomware, is a significant threat to banks and their customers. Rossi et al. (2021) identify malware as one of the most common threats, noting that ransomware attacks have increased exponentially in recent years. According to Pallangyo (2022), cybercriminals often use malware to steal financial information or modify transactions illegally.
3. *DDoS attacks:* Attacks aimed at overloading servers and disrupting financial services are another major challenge. Darem et al. (2023) point out that DDoS attacks have been increasingly used as a tactic to divert attention from other, more sophisticated attacks, such as background data theft.
4. *Insider Attacks:* Internal employees pose a particular threat to system security, having direct access to critical information. Mitnick and Simon (2003) argue that insider attacks are among the most dangerous, as they exploit privileged access and often remain undetected for a long period.

Factors Affecting the Spread and Success of Attacks

Factors that affect the success of cyberattacks include technology, human error, and the economic motivations of attackers:

Human Error: Most phishing and malware attacks succeed due to human error. Alkhalil et al. (2021) shows that the lack of training and awareness of customers and employees is one of the biggest weaknesses that attackers exploit.

Outdated Equipment and Systems: Financial institutions often fail to update their IT systems, making them vulnerable to known attacks. Kopp et al. (2017) argue that this lack of investment is one of the main factors influencing the spread of attacks.

Complexity of Infrastructure: Modern banks use very complex IT systems, which often create spaces for unexpected vulnerabilities. Rossi et al. (2021) emphasize that the interaction between different systems increases susceptibility to cyberattacks.

Economic and Social Motivation of Attackers: Most attacks are motivated by financial gain, but some are driven by ideological or political motives.

Madnick et al. (2024) analyze the evolution of global cybersecurity norms, emphasizing that the growth of cybercrime has been influenced by the lack of common standards and international cooperation.

Safeguards to Reduce Threats

To address this, the literature recommends safeguards:

1. MFA is one of the most effective measures to reduce risk that is not related to credential theft. Dupont (2019) suggests considering MFA as a standard across all e-banking platforms. 2. User and Employee Training: Educating customers and employees about their awareness has occurred. Chenoweth (2005) and Gayan Nayanajith et al. (2019) emphasize that awareness campaigns and personalized training can minimize human errors.
2. Implementation of Advanced Technologies: Technologies such as blockchain and AI are successful in improving shopping services. Rossi et al. (2021 Dupont) (2021) recommend using e1 technology to detect anomalies and protect against attacks.
3. Improving Infrastructure Technology: Investments in new systems and changes in the rules and software used are being created. Pallangyo (2022) emphasize that this approach reduces exposure to cyberattacks.

Global and Regional Perspectives on Cyber Threats

The contemporary literature emphasizes global changes and regional challenges in the cybersecurity of e-banking. Macierzyński Boczoń (2022) how the COVID-19 pandemic affected the analysis of attacks in Poland, highlighting that the massive shift towards online and facing the challenges of people in America. On the other hand, the study of Jibril et al. (2020) shows that the perception of a role plays an important role in the adoption of e-banking, suggesting the need for measures for customer trust. Regional studies such as that of Maphosa. This reflects a necessity for personalized cyberfriend strategies in different contexts.

Using Advanced Technology for Security

The use of technology such as blockchain and artificial intelligence (AI) has gained a lot of attention in the scientific literature. Rossi et al. (20221) emphasize that blockchain offers high security due to its characteristics of decentralized and immutable nature. Similarly, Dupont (2019) suggests that AI detects anomalies faster and prevents potential attacks.

Proactive peer-to-peer strategies, associated with advanced financial institutions, as done by Kay et al. (2021), focus on advanced technology and educating people, creating an integrated system of protection.

Social and Psychological Impact on E-Banking Security

The psychological and social impacts of cyberattacks are also widely documented. Eleyan et al. (2022) results that lack of cybersecurity education leads to high susceptibility to attacks such as phishing and malware. Similarly, the study by Al-Alawi et al. (2023).

Cybersecurity in e-banking is a challenging one that requires a multi-layered approach. Threats such as phishing, malware, and malicious insider attacks, as well as common human errors and outdated technologies, increase vulnerability to them. Through safeguards such as MFA, ongoing training, and the implementation of advanced technology, security providers can protect their systems and maintain customer trust.

3 Methodology

This study is designed to address the main cyber threats in e-banking, to identify the factors that influence the spread and success of these threats, and to propose protective measures to minimize them. A qualitative approach was chosen to analyze this complex issue and to explore the perspectives of professionals in the field of cybersecurity and e-banking. The qualitative approach offers flexibility to understand the dynamics and complexities in this area based on the experiences and practical analysis of experts.

This is a case study that focuses on financial institutions and the experiences of cybersecurity experts in in Kosovo. The study aims to help develop a deeper understanding of the security challenges and practical solutions that can be applied.The target population for this study consists of cybersecurity experts, IT managers, and bank representatives involved in managing e-banking.

Sample size: The sample includes 5-7 participants, who represent different professional profiles in cybersecurity and the banking sector. • Sample selection method: The selection of participants was carried out through a purposive approach, selecting individuals with specific knowledge and experience on threats and protective measures in e-banking. The process included participants with at least 3-5 years of experience in information security or e-banking, as well as those engaged in managing cyber incidents and developing protective strategies for the financial sector. Participants provided their information anonymously to maintain confidentiality and to ensure an objective analysis of the current cybersecurity situation in e-banking.

Data Collection Methods

Data Sources-Semi-structured interviews: These were conducted to collect detailed data and explore participants' perspectives on cyber threats and protective measures. In addition to semi-structured interviews, questionnaires were also conducted to collect data from e-banking users.

Data Collection Process

The interviews were conducted physically, adapting to the availability of the participants. The questions were open-ended to encourage in-depth discussions and to obtain authentic perceptions.

An interview guide was prepared to ensure that the main topics were covered:

- The most common types of cyberattacks on e-banking.
- Factors contributing to the success of these attacks.
- Effectiveness of current protective measures.

Data Analysis

- Thematic analysis was used to identify recurring patterns and themes in the participants' responses.
- Data Coding: The collected data was coded and analyzed manually or through appropriate thematic analysis software, identifying recurring themes and patterns.
- A comparison of data from different sources was conducted to ensure that the results were consistent and evidence-based.

4 Results and discussion

Based on the responses from the interviews with bank employees, key themes were identified that summarize the challenges and safeguards related to cybersecurity in e-banking. These themes are presented below.

Table 1: Thematic Analysis

Answers	Initial Interpretation	Encryption	Themes
"Phishing attacks trick customers into sharing their credentials."	Customers fall prey to scams through fake emails or websites	Phishing	Main threats
"Malware is used to steal data or crash systems."	Malicious software can infect users' devices to obtain data.	Malware	Main threats

Answers	Initial Interpretation	Encryption	Themes
"Servers are overwhelmed by DDoS attacks, causing service disruptions."	Attackers use high traffic to render systems unusable.	DDoS attacks	Main threats
"Individuals with insider access could exploit their privileges for malicious purposes."	Internal employees can abuse their access to damage systems.	Insider Attacks	Main threats
"We teach customers to avoid clicking on suspicious links."	Customer education helps reduce successful attacks.	Customer education	The Role of Training
"Training helps staff recognize and avoid mistakes that could compromise security."	Trained personnel are better able to detect threats and take action.	Employee training	The Role of Training
"MFA requires more than one authentication method, increasing security."	Security is increased by requiring more than one form of identification.	MFA (Multi-Factor Authentication)	Technological Measures
"Real-time monitoring helps identify threats."	Continuous monitoring helps detect potential attacks.	Monitoring	Technological Measures
"Systems and devices should be updated regularly to minimize vulnerabilities."	Improved technology helps protect against new attacks.	IT Update	Strategic Improvements
"Identifying unusual behaviors helps prevent attacks."	Abnormal behaviors may be indicators of a possible attack.	Behavior analysis	Strategic Improvements
"Many customers are unaware of cyber risks."	Cybersecurity education is still low among users.	Awareness	Social and Psychological Factors
"Cyberattacks can reduce confidence in the security of electronic banking services."	Users may feel unsafe using online services after an attack.	Customer trust	Social and Psychological Factors

Source: Authors

Key Cyber Threats

Employees highlighted several key threats affecting e-banking systems, including: *Phishing:* Phishing attacks have been identified as a key challenge, exploiting human factors to obtain personal and financial data.

Malware: Specialized malware, such as Trojans and ransomware, is widely used to steal data or disrupt operations.

DDoS attacks: These attacks aim to disrupt services by overwhelming bank servers.

Insider attacks: Individuals with insider access pose a particular threat, as they can exploit privileges for malicious purposes.

The role of training and awareness

A recurring theme was the importance of education and training:

Employees: Regular training helps reduce human error and improves the ability to recognize threats.

Customers: Educating customers to avoid clicking on suspicious links and to store passwords securely is essential to increase security.

Practical simulations: Participants suggested simulations of phishing attacks to help employees better deal with these threats.

Effectiveness of technological measures

Technological measures were highlighted as one of the most effective ways to improve security:

Multi-Factor Authentication (MFA): MFA was cited as a critical security layer for protecting customer accounts.

Real-time monitoring: Advanced monitoring systems help detect and isolate threats in time.

Advanced technologies: The use of technologies such as blockchain and artificial intelligence (AI) offers new opportunities for anomaly detection and transaction protection.

Strategic improvements

Employees suggested several directions for future improvements:

Modernization of IT infrastructure: Regular updates of systems and equipment were highlighted as an urgent need to minimize vulnerabilities.

Use of behavioral analysis: Identifying unusual user behaviors would help prevent potential attacks.

International cooperation: The creation of global standards and information sharing between institutions was proposed to better combat cybercrime.

Social and psychological factors

Another important aspect was the impact of social and psychological factors:

- *Low awareness:* Lack of education on cybersecurity makes customers and employees more susceptible to attacks.
- *Impact on customer trust:* Cyber attacks can negatively impact the perception of security and customers' trust in e-banking services.

5 Conclusions

This study confirms that the main threats in e-banking are a growing challenge, with threats such as phishing, malware, DDoS attacks and insider attacks requiring advanced protective measures. Technological measures such as multi-factor authentication and continuous monitoring are critical for data protection, while

customer education and employee training can significantly reduce the risks of attacks.

Comparing this study with previous research, it is seen that cyber threats are constantly evolving and require increasingly advanced protective measures. Other studies highlight that low awareness and lack of investment in security are key factors that increase vulnerability to attacks. Improving IT infrastructure and using artificial intelligence for threat detection are some of the latest trends recommended to face current challenges.

Compared with findings from different countries, the most effective strategies are those that combine technology, education and international cooperation to address cyber risks in the banking sector.

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Smart Energy, Conscious Future: The Role of Artificial Intelligence in Energy Efficiency

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Artificial intelligence (AI) offers innovative tools to enhance energy efficiency and promote sustainable consumption. This study explores the role of AI in transforming energy use patterns and raising awareness, particularly in light of behavioral changes triggered by the 2021 energy crisis. Based on a quantitative online survey of over 400 Hungarian participants, the research examines how AI-supported systems—such as digital platforms and personalized feedback tools—can reduce fossil fuel dependence and support the adoption of renewable energy. The findings highlight AI's potential in promoting conscious energy behavior through targeted, low-cost, and scalable solutions.

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1 Introduction

Energy efficiency and energy awareness have become critical issues both globally and societally, particularly in the context of sustainability goals and efforts to combat climate change. In recent years, the instability of energy markets, the volatility of fossil fuel prices, and concerns about energy security have highlighted the growing importance of energy-efficient solutions. The energy crisis that emerged in 2021 had a particularly significant impact on Hungary, where rising energy prices compelled a substantial portion of households to reconsider their consumption habits. As a result of the crisis, energy-conscious behavior rapidly became one of the most important adaptation mechanisms. Energy-saving practices – such as the modification of heating habits, the use of energy-efficient appliances, and the reduction of non-essential energy consumption – have gained widespread popularity among Hungarian households. Moreover, the energy crisis has underscored an inescapable reality: energy awareness is not merely an economic necessity but also a key driver for achieving climate protection objectives.

2 Literature Review

Energy efficiency and energy awareness are considered essential factors in promoting sustainable development, especially in the context of the energy crisis and climate change. The growing integration of artificial intelligence (AI) and machine learning (ML) technologies within the energy sector has created new opportunities for reducing energy consumption, improving demand-supply management, and encouraging energy-conscious behavior (Ukoba et al., 2024). The promotion of energy-efficient technologies and consumer practices not only contributes to the reduction of global carbon emissions but also alleviates the financial burden of rising energy costs on households and businesses (Gielen et al., 2019).

In Hungary, public energy awareness has shown significant progress in recent years; however, the widespread adoption of energy-conscious practices is still not a general norm (Szakály et al., 2021). Research indicates that regional and social disparities characterize energy awareness levels in Hungary. Although a large portion of the population acknowledges the importance of energy efficiency, the widespread diffusion of energy-conscious behaviors is still hindered by factors such as financial limitations, a lack of information, and skepticism toward modern technological

solutions. The 2021 energy crisis, marked by the drastic and volatile rise in energy prices, had a significant impact on consumer energy use habits (Gajdzik et al., 2023). Despite growing attention to energy-conscious mindsets and energy-efficient behaviors, numerous obstacles continue to impede their widespread adoption among the Hungarian population, including:

- *Entrenched consumption patterns:* A significant portion of the Hungarian population follows long-established energy consumption habits, many of which reflect energy-wasting behavior (Szakály et al., 2021). During periods of low energy prices – especially under the influence of public utility cost-cutting measures—there was no strong economic incentive for households to invest in energy efficiency or to modify their consumption habits (Gadenne et al., 2011).
- *Limited financial resources and living conditions:* The research highlights that one of the main barriers to energy efficiency is the lack of financing options (48.9%) and inadequate financial or living conditions (11.8%).
- *Lack of knowledge:* Some consumers are either unaware of their options (2.8%) or do not understand how and to what extent they could save energy at home (6.7%), nor how their individual decisions impact their own energy consumption and the environment. This is especially true in rural areas and among lower-income households, where environmental awareness and the importance of long-term savings are often less relevant due to financial constraints.
- *Financial barriers to energy efficiency investments:* The acquisition and installation of energy-efficient technologies – such as insulation, window replacement, or modern heating systems – represent significant financial burdens for many households (39.9%). Although the energy crisis has increased interest in such developments, a high proportion of the population still lacks the resources to undertake energy efficiency investments. Consequently, energy-saving efforts are often limited to daily consumption reductions (e.g., lowering heating or reducing lighting) rather than comprehensive technological upgrades (Remsei et al., 2024).
- *Cultural and perceptual barriers related to energy use:* Historically, energy has been perceived by much of the Hungarian population as a "basic service" with limited recognition of its intrinsic value. Some segments of the population have regarded utility services as a "necessary evil," resulting in weak

associations between energy efficiency and sustainability goals. Notably, 3.4% of respondents do not consider energy efficiency important at all, and 1.9% do not see the relevance of renewable energy systems.

In response to the 2021 energy crisis, a shift in perspective began to emerge within the Hungarian population, as broader segments of consumers recognized that energy awareness is no longer solely an environmental issue but also a tool for economic survival. The surge in energy prices led to growing interest in energy-saving solutions; however, the transformation of consumption patterns cannot yet be considered widespread (Szakály et al., 2021).

Today, energy awareness, energy efficiency, artificial intelligence (AI), and online communication have become closely intertwined components of sustainable energy management (Gielen et al., 2019). AI-based systems analyze consumption patterns in real time, optimize energy use, reduce waste, and simultaneously enhance user comfort (Iorgovan, 2024). AI enhances energy awareness by offering personalized feedback and identifying inefficient habits (Bennagi et al., 2024). Combined with digital communication, it serves as both a technological and behavioral tool, empowering consumers to adopt more sustainable energy practices (Rozite et al., 2023).

3 Materials and Methods

The study employed a quantitative methodology, using an online questionnaire via the Surveyplanet platform to examine the impact of the 2021 energy crisis on Hungarian households' attitudes toward renewable energy and energy awareness. The survey covered four thematic areas: knowledge, attitudes and perceptions, user experiences, and demographics. In total, 423 individuals participated, primarily private respondents open to renewable energy solutions. Data were collected through convenience sampling via social media and mailing lists. The sample was demographically diverse in terms of age (18–65+), gender (48% female, 52% male), and location (urban and rural). Despite its relevance, the study has limitations: the sample is not representative, the design is exploratory, and certain items may have caused ambiguity in whether respondents referred to personal or societal awareness. These factors limit generalizability and underscore the need for more robust, representative future research.

4 Results

The findings of this study provide important insights, as the identified consumer attitudes, behavioral patterns, areas of interest, and media consumption habits inform practical applications for artificial intelligence (AI) solutions. Respondents perceived 87.5% of the Hungarian population as not energy-conscious—a reflection of societal attitudes rather than self-assessment. This highlights notable potential for targeted awareness and behavior-change initiatives. By leveraging appropriate online platforms, a broader segment of consumers can be reached and educated regarding both energy efficiency and energy awareness. More than half of the respondents (66.6%) indicated that they seek information about renewable energy or energy efficiency through digital platforms. Social media platforms play a prominent role in daily life, with 21.5% of respondents primarily obtaining related information via social media. This considerable proportion represents a relevant target group not only in the domain of online communication but also within the context of energy efficiency. For instance, utility providers could achieve substantial progress through the development of a free, downloadable digital application targeting this digitally engaged 66.6%. Furthermore, 2.7% of respondents acknowledged that educational content provided by energy suppliers influences the spread of energy-efficient and renewable energy practices. Moreover, 76.5% believe that energy suppliers bear significant responsibility in promoting energy-conscious behavior among the population, thereby contributing to the broader adoption of energy efficiency.

The analysis of energy consumption patterns among private individuals revealed that Hungarian households primarily rely on natural gas (39.8%) and electricity (34.9%) to meet their energy needs. Additionally, 5.7% use heat pumps, 11.9% utilize wood, and 7.7% rely on other sources. This information is particularly relevant for this study, as it enables utility providers to offer more tailored and practical recommendations to consumers, thereby promoting energy efficiency based on a deeper understanding of household energy consumption habits. Notably, 39.9% of respondents reported being unable to afford energy-efficient systems, suggesting that this segment could benefit most from low-cost, digitally delivered solutions. Identifying both internal and external motivators (e.g., financial or psychological factors) would enable providers to further personalize their advice. A significant portion of respondents (48.9%) reported a lack of personal capital or inadequate financial circumstances to invest in energy-efficient systems. However, 65.3%

actively follow news and information related to renewable energy and energy awareness, while 55.3% have considered switching to a renewable energy source, making them a promising target audience for online campaigns promoting energy efficiency. While the surveyed group demonstrates an emerging commitment to energy-conscious and energy-efficient behaviors, their efforts remain in the early stages, constrained by limited financial means and basic energy-saving options currently available to them.

A substantial share of respondents (78.7%) reported engaging in energy-efficient practices in their daily lives, including the use of energy-saving appliances (28.5%), conscious energy consumption (32.7%), unplugging devices after use (17.5%), and the adoption of smart home technologies (7.8%). Furthermore, 9.2% reported using renewable energy sources to meet their energy needs. Only 0.7% of participants indicated that they do not make any effort to live an energy-conscious lifestyle.

5 Recommendations

Based on the identified behavioral patterns, attitudes, and consumer habits, the following AI-driven recommendations are proposed to enhance energy awareness and promote energy efficiency in practice:

- ***AI-based digital educational platform with targeted communication:*** Given that 87.5% of respondents perceive the Hungarian population as not energy-conscious and 66.6% rely on digital platforms for information, it is recommended to develop an AI-driven educational platform. This platform would segment target audiences based on interests, attitudes, and online media consumption patterns, offering personalized content while considering user motivation (e.g., cost savings, environmental protection, comfort).
- ***Intelligent mobile application offering personalized energy-saving tips:*** For the digitally active segment that remains less receptive to energy-efficient technologies (39.9%), an AI-based application could provide tailored recommendations based on users' energy sources (e.g., gas, electricity, heat pump). As digital engagement often reflects general media use rather than sustainability awareness, the app should combine personalized advice with educational content to encourage behavioral

change. Continuous consumption monitoring and gamification (e.g., challenges, rewards) could further support motivation (Kranz et al., 2010).

- ***AI-generated consumer motivation map for energy providers:*** As 76.5% of respondents emphasized the responsibility of energy providers in increasing energy awareness, AI could assist providers in developing detailed motivation maps. These maps would account for consumers' financial situations, energy habits, and attitudes, thereby facilitating the creation of customized services and supporting targeted incentive programs (e.g., leasing or installment plans for energy-efficient devices) (Li & Yuan, 2024).
- ***AI-driven, low-cost energy efficiency recommendation system*:** Given that 48.9% of respondents lack capital for the installation of energy-efficient systems, an AI-based recommendation engine could propose feasible, low-investment but effective energy-saving solutions tailored to individual financial, demographic, and housing conditions. The system would also calculate potential savings and payback periods (Dzwigol et al., 2024) and provide educational materials and step-by-step implementation guides.

Clarifying the operational principles of AI-based systems enhances the practical relevance of the proposed recommendations. These systems typically utilize user-generated and sensor-derived data – such as smart meter readings or appliance usage patterns – to identify inefficiencies and generate personalized feedback. Technologies like Google Nest and Tesla Powerwall exemplify how real-time optimization can improve both the effectiveness and user acceptance of such applications.

6 Conclusion

The results of this study confirm that the energy crisis has heightened energy awareness among the Hungarian population and increased interest in renewable energy sources. Among respondents, energy efficiency considerations and sustainable consumption practices have gained prominence, driven by rising energy prices and energy market instability. The findings also highlight the pivotal role of AI-based solutions and online communication channels in fostering energy awareness. The implementation of intelligent technologies can further support households and businesses in identifying and addressing energy-wasting behaviours

(Yussuf et al., 2024), positioning them as active participants in sustainability initiatives.

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What Are the Specific Challenges for SMES in Complying With ESG Reporting?

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As a part of a wider research, we proved that Hungarian SMEs (small and medium enterprises) are not just intrinsically motivated to be sustainable and report their sustainable activities and indices but are also compelled to do so by legislation. However, they face limitations such as a lack of resources and knowledge about sustainability. Partly, sustainability should be observed and reported as a part of accounting and corporate reporting. However, sustainability reporting mainly means a form of non-financial reporting that enables companies to communicate their progress in sustainability parameters. Sustainability reporting has only a few compulsory templates and both the EU and national ESG[1] regulations are constantly changing, which results in a considerable need for support from entrepreneurs. The first section of this paper provides an extended overview of the various non-financial reporting in historical order. While bigger companies have dedicated departments or employees who are responsible for ESG, the SMEs are looking for help, and require further support, information, training, and advice from outside. This research aims to study experts' interviews and explore how the experts in regulation, education and consultancy are thinking about the opportunities and challenges for SMEs regarding ESG reporting.

Keywords:
sustainability,
ESG,
non-financial reporting,
expert interviews,
SME sector

JEL:
Q56

[1] ESG stands for environmental, social, and governance factors that companies measure when analyzing a company's sustainability efforts from a holistic view.

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1 Introduction

The roots of the international environmental movement go back to the second half of the 20th century when the first environmental movements began in Europe and North America. The term 'sustainability' or 'sustainable development' (SD) appeared in the international literature in the early 1980s (Brown, 1981, UN, 1987). Sustainable development is based on three interlocking dimensions: economic, social and environmental, and all three are interconnected, with their interactions and hierarchy - the environmental dimension is the basis, and only within it can the social dimension be understood, followed by the economic dimension as a subsystem of the system. By the beginning of the 2020s, the concept of sustainability had been mostly approached and translated into corporate practice by the term Environmental-Social-Governance, abbreviated ESG (UN, 2004, Hardyment, 2024).

Small and medium-sized enterprises (SMEs) are the cornerstone of many developing countries' economies - contributing significantly to economic growth, employment and innovation, and of course sustainability. According to Generali and SDA Bocconi's report (2023), 44% of their SME sample have adopted a more formalized approach to sustainability or are in the process of adopting one. Contrary, 37% of SMEs showed no interest in any ESG strategy. This can be explained through the fact they have limited access to tools to measure and monitor their sustainability. Additionally, the lack of institutional support and public incentives are severe barriers. Another serious obstacle is the lack of standardized methodology tailored to SMEs. As our previous research shows SMEs have limited human and financial resources to produce or provide non-financial reports, and lack the necessary expertise, which situation is even worse if they have to comply with more guidelines' expectations (Kolnhofer-Derecskei et al., 2024).

This paper provides an extended summary of the non-financial reporting format of sustainability interpreted in the ESG concept. In the empirical part, 6 experts were interviewed and asked about the opportunities and challenges for SMEs regarding legal obligations and non-financial reporting. Finally, practical implications are given to policymakers and ESG-focused institutions.

2 Theoretical Background / Literature review

2.1 Non-financial reporting – a historical overview

The history of CSR - Corporate Social Responsibility - has been closely linked to sustainability in the years of development of SD theory and practice. The concept of CSR has been widely recognised and used since the 1970s, first in the US and later as the need for accountability and transparency in business increased worldwide. As a result, from the 1990s onwards, more and more companies started to report on the impact of their activities on their stakeholders. The topics initially covered mainly by environmental and/or occupational health and safety reporting became more complex, and this was reflected in the naming of non-financial reports (Győri and Csillag, 2019). By the early 2020s, the most common names for reporting in line with ESG principles were non-financial reporting and sustainability reporting (Lippai-Makra and Kovács, 2023), which we use as synonyms in this paper.

There are four main theories in the literature about the factors that motivate companies to produce non-financial reports (Lippai-Makra and Rádóczi, 2021, Nada and Győri, 2023). The principal-agent theory suggests that this is how companies seek to reduce information asymmetry and its costs (Girella et al., 2019). According to the signalling theory, company insiders and managers provide data and information through various means, including non-financial reports, in order to show their excellence, and goodwill and avoid disputes (Mitchell, 2006). According to stakeholder theory, stakeholder engagement is key to the long-term success of the company and is, therefore, a business interest, but also a moral obligation, arising from the fact that stakeholders are involved in the creation of corporate value and are affected by the company's operations, and thus have a legitimate expectation of transparency (Grüning, 2011, Lippai-Makra and Kovács, 2021). Legitimacy theory emphasises the aspect that the company achieves legitimacy within the society in which it operates through the communication of information (Beck et al., 2017).

Corporate reporting is defined by Gibbins et al. (1990) to include the intentional disclosure of both financial and non-financial information. This disclosure may be mandatory or voluntary and may be made by formal or informal methods. Various forms of corporate communication may be used, such as analyst presentations, investor materials, interim reports, prospectuses, press releases and corporate

websites, but the most complete information of all is contained in corporate reports, which may contain both financial and non-financial information. A whole range of existing academic research attests to the benefits that companies can experience from active interaction with stakeholders (Abeysekera, 2013, Shehata, 2014, Demartini and Trucco, 2017).

According to Buallay et al. (2020), the disclosure of non-financial information has gone through four main stages. Initially, companies focused on their social responsibility, but later, particularly in the wake of major pollution scandals, stakeholders started to pay more attention to the impact of companies on the environment, and this was the first topic to be reported. Subsequently, the concept of sustainability emerged, which as explained above, encompasses aspects of social, environmental and economic transparency and accountability, but usually in the form of separate financial and non-financial reporting. Finally, the concept of integrated disclosure emerged in the final phase, which means the disclosure of financial and non-financial information in a single report.

2.2 Regulation and practice of non-financial reporting

Whether or not non-financial reporting in general can contribute to transforming the economic rationale towards more sustainable management is still the subject of further research (Christensen et al., 2021, Gillian et al., 2021, Bini et al., 2023), however, corporate and auditing practice is increasingly adopting and incorporating a sustainability (Perrini, 2006) and more recently ESG (Hardyment, 2024) approach. A multi-directional and detailed analysis of current sustainability reporting practices is carried out annually by KPMG. In their survey published in autumn 2022 (KPMG, 2022), KPMG examined the sustainability reporting and websites of the G250 - i.e. the 250 largest companies in the world by revenue based on the 2021 Fortune 500 ranking - and the N100 companies in 58 countries - i.e. the 100 largest companies by revenue based on territorial and jurisdictional approaches in 58 countries, a total of 5,800 companies.

The survey found that 96% of companies in the G250 group report on sustainability issues, compared to 79% of N100 companies. This is an improvement from 18% and 12% respectively in 1993. In Asia and the Pacific, 89% of N100 companies report on sustainability. This is followed by Europe with 82%, the Americas with

74% and the Middle East and Africa with 56%. Within Europe, there is a disparity, with the Western European N100 reporting at 85% compared to 72% for Eastern European companies.

The above should be reassured, as the world's largest companies are concerned about sustainability and publish information about it. However, we also need to look at the extent to which companies are following the same practices and standards for sustainability reporting. As of Autumn 2024, the most well-known and dominant sustainability reporting standards that cover ESG aspects are:

Table 1: Best-known sustainability reporting standards and guidelines

CDP	Carbon Disclosure Project
CDSB	Climate Disclosure Standard Board Standards
ESRS	European Sustainability Reporting Standards
GGP	Greenhouse Gas Protocol
GRI	Global Reporting Initiative
IIRC IR	International Integrated Reporting Council Integrate Report
SASB	Sustainability Accounting Standards Board Standards
SDG	UN Sustainable Development Goals
TCFD	Taskforce on Climate-related Financial Disclosures
TNFD	Taskforce on Nature-related Financial Disclosures
WEF SCM	World Economic Forum Stakeholder Capitalism Metrics

Source: own elaboration

As shown in Table 1, there are many different reporting regulations and guidelines for sustainability reporting, which on the one hand make it difficult for companies to interpret and apply, and on the other hand limit comparability for stakeholders. Many large companies apply the standards and recommendations of several organisations, putting SMEs in their supply chains in an almost impossible situation.

3 Methodology

In 2025, January and February six expert interviews were carried out by two of the authors. The structured interview guide contained several questions regarding sustainability, ESG and non-financial reporting related to Hungarian SMEs. Table 2. provides an overview of our sample:

Table 2: Sample

Interviewee 1. Male	ESG expert and Head of ESG Related Activities by Supervisory Authority for Regulatory Affairs of Hungary
Interviewee 2. Male	Lawyer specified in professional ESG reporting
Interviewee 3. Male	Associate Professor and Senior Research Fellow in Sustainability
Interviewee 4. Male	Assistant Professor and Sustainability Office Leader
Interviewee 5. Male	Head of Sustainable Financial Analysis by Hungarian National Bank
Interviewee 6. Female	ESG expert and PhD student in sustainability studies

Source: own elaboration

The interviews were conducted by two researchers and clarified transcripts were confirmed by all interviewees. The transcripts are analyzed in a deductive way based on the before detailed grounded theories (Mitev, 2021). Meanwhile (in March), we have extended the sample of the experts and altogether 9 interviews were conducted and under evaluation. In this paper, only those five are partly evaluated that were available in February. The original guide included 5 main topics and topics were tailored to each expert's field. In this paper, one part was examined where ESG experts were asked "What are the specific challenges for SMEs in complying with the ESG reporting regulation? What do they think, how prepared the Hungarian SMEs are to meet the compliances?".

4 Results

All answerers agreed that SMEs are aware of non-financial reporting in ESG.

Most of them have to comply as suppliers for bigger companies. As one interviewee said, "supplier in the supply chain of the largest companies, they are already encountering daily how they receive the various questionnaires from the large company, which they have to fill in since the large company must also screen its suppliers for the ESG report for various reports, so on the one hand, even Hungarian SMEs are already encountering plenty of them." (interviewee 2.) Additionally, experts said that "The SME sector is working under a lot of pressure, the economy is inherently in favour of the big guys, and as an SME in Hungary it is very difficult to see any real success SME stories." (interviewee 3.) Meanwhile, as interviewee 4. highlighted government can also put extra pressure on SMEs and "the legal obligation (for SMEs) will also emerge sooner or later."

Industries and fields where an SME operates show differences, while suppliers e.g. agriculture can have more support from the vendors or distributors, but an SME which is the end service provider, will have to prepare these reports at its own pace.

In smaller companies where there is no capacity to do this, it is a serious extra workload on top of the day-to-day work. Although as interviewee 5. mentioned, "Obviously a large company has more resources to build this kind of system, but in return, a micro company has practically I don't know a quarter as many questions as a large company, and they are much easier to answer."

In sum, SMEs are way aware of non-financial reporting in ESG, many are required to comply as suppliers for larger companies. Legal obligations may emerge that can put additional pressure on SMEs. Since smaller companies have less capacity to prepare ESG and other types of non-financial reports regardless of the type of standards or guidelines.

5 Discussion

According to KPMG's 2022 analysis, GRI is the most dominant standard used worldwide, with 68% of N100 companies and 78% of G250 companies using it, and this spills over to smaller companies in the value chain. However, from 2025, the scope and proportion of the standard will change due to the entry into force of the European Union's ESG legislation, most notably the CSRD (Corporate Sustainability Reporting Directive, 2022/2464/EU, EP & EC, 2022). It is expected that the application of the GRI will be superseded, as the EU regulation has elaborated the European Sustainability Reporting Standards (ESRS, EFRAG 2022a, 2022b, 2024a, 2024b), which will be the mandatory basis for reporting under the CSRD, even if it may be complemented by other existing guidance in practical application.

Under the CSRD, from 2025 companies will have to share significantly more sustainability information, and ESRS indicators with stakeholders than before, and integrate it with financial data. In fact, in 2025 only the largest European companies will have to report on the year 2024, but a year later all large companies, and in 2027 all listed SMEs will have to publish their sustainability reports.

In Hungary, in addition to compliance with the CSRD, the requirements of the ESG Act[1] (Government of Hungary, 2023) also apply to sustainability issues, so companies will need to develop and operate a documented ESG risk management system, with a particular focus on the sustainability impacts of their supply chain. On the one hand, this is an additional burden - especially given the different logic of the ESG Act, for example, there is no materiality analysis but companies have to answer questions from a predefined ESG questionnaire - on the other hand, it contributes to improving the quality not only of ESG reporting but also of non-financial reporting, by setting higher standards for data collection and management through the whole value chain.

6 Conclusions and managerial implications

Due to these excessive regulations and bureaucracy, SMEs perceive these barriers more intensely. Clear regulations and reduction of bureaucracy, support, training, and partnerships with ESG-focused contributors are recommended. Firstly, initiatives and campaigns demonstrating the ESG benefits of sustainability are advocated. Non-financial reporting obligations should lay on clear and proportionate frameworks and templates for SMEs, SMEs can be reached through partnerships and collaboration with relevant stakeholders and the business community. An ESG framework that integrates environmental, social and governance considerations is becoming an increasingly vital factor for businesses in securing access to finance and maintaining their reputation and position in competition. Nevertheless, the question is given whether a small enterprise with limited resources really needs to provide an ESG report.

In Hungary, the Supervisory Authority for Regulatory Affairs of Hungary (SARA) was established to create stable and predictable operational and regulatory conditions for oversight of the corporate sustainability reporting system (ESG). One of our interviewees is representing this authority, as he said "If we are talking about reporting obligations, then I see that it is not the intention to include SMEs in this scope, neither in CS3D, nor in CSRD, nor the ESG Act, because we know that this can be a very strong extra obligation, which in turn can harm competitiveness if a

[1] As the ESG Act is not explicitly about non-financial reporting, but about building and operating an ESG-related risk management system and has a very different logic for measuring ESG performance, that is why we have not included it in the comparative frameworks of non-financial reporting.

company has to allocate too many resources to it. In addition, the ESG process starts from the very beginning, so that by the time they can produce real and high-quality material, it takes a lot of time, which is not necessarily the case if the report is to be brought to the SMEs in the European competitiveness context." (interviewee 1.).

7 Additional information

Meanwhile on 26 February 2025, the European Commission published the Omnibus legislative package, which not only dashes the foundations of EU sustainability regulation, but also proposes to redefine future corporate activities and their reporting obligations. It also has the declared aim of simplifying regulation, increasing the competitiveness of businesses and promoting more sustainable economic activity. It means that the changes to the legislative environment are further complicated by this "stop-the-clock" sustainability reporting recently suggested by the EU (European Commission, 2025). This decision temporarily suspends strict compliance deadlines, granting large companies with fewer than 500 employees and SMEs a two-year relaxation, meaning that SMEs will have to submit their first sustainability report in 2028 instead of 2026. The decision has been taken to reduce the administrative burdens faced by companies within the European Union, particularly in the context of the turbulent changes being experienced in the global economic environment. The Hungarian ESG law (Kavosz, 2025) underwent a rapid revision in the wake of the EU amendment, with the legal requirement for SMEs to disclose ESG information only becoming effective in 2028. This regulatory change will reduce the administrative burden in the short term but raises new questions. There is a question - highlighted by both the EU and the Hungarian government - that although ESG reporting is not mandatory for a few years, companies should use this delay to build up their data collection methods and systems.

Many companies that have been preparing for compliance for some time may decide to prepare voluntary ESG reports. This way, when they are required to do so, they will not feel that compliance is an overwhelming administrative burden. In addition, even if there is no legal obligation, institutional investors and banks alike prefer companies that have ESG reporting and sustainability reporting.

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What Would the Younger Generation Give Up for a Better, More Sustainable Future?

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The UN defined sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs. That partly means to satisfy the needs of the present and to live a happy and contented life. At the same time, this also means that we should give up remaining within the ecological limits of the Earth. This is one of the major challenges of our century. The PRME Youth Talks survey asked young people how they see the world: what they hope for and what they fear for the future. The questions included a block on what they would and would not give up for a better future. Among the responses were several issues related to sustainability. Based on 80 PRME interviews, this research aims to explore younger generations' opinions about conscious consumption. We found that young people are willing to sacrifice are material consumption, their free time and personal ambitions. This generation seems to be ready to work for a sustainable future.

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1 Introduction

The consumption pattern of the industrialized world is overusing the resources of the Earth (Chen et al, 2022). Besides governments and companies, consumers also have to change their behaviour to be more sustainable. A socially responsible consumer is an individual who considers the externalities of his/her private consumption with respect to environmental and general social concerns (Han & Stoel, 2017). Responsible sustainable consumer behaviour involves a complex pattern of environmental and social issues, in line with the view of sustainability as a construct with both environmental and social pillars (Hosta & Zabkar, 2021). Webb et al., (2008) identified three possible dimensions of socially responsible consumption: (1) purchasing based on corporate social responsibility practices, (2) recycling, and (3) rejecting or reducing the purchase of environmentally and/or socially harmful products. The latter category is at the centre of our analysis and leads to our research question: what are those things which young adults are ready to give up for a better future?

For the qualitative analysis we use the interviews of the international project "Youth Talks" of Principles for Responsible Management Education (PRME). PRME uniquely gathers the opinion of the young generation (15-29 years old) by using open-ended questions to understand their needs, hopes, and fears in connection with topics like climate change, meaningful work and education.

2 Theoretical Background / Literature Review

White et al. (2019) tried to identify the key drivers of sustainable consumption change. Their SHIFT framework highlights the role of (1) social influence, (2) habit information, (3) individual self, (4) feelings and cognition and (5) tangibility in motivating the change in consumer behaviour. Descriptive norms as the dominant behaviour, beliefs and norms of a reference group (Gelfand & Harrington, 2015) have a fundamental influence on the behaviour. Social identity also plays an important role in consumption, - especially in the elements of consumption that are visible to others. If consumers are members of a group in which sustainable behaviour is common, then it has a high probability that they will behave similarly (Han and Stoel, 2017). The role of different reference groups' norms is especially important when we focus on young adults. Finally, White et al. (2019) mention social

desirability, which is the reason why consumers try to make positive impressions on others by choosing sustainable products (Green and Peloza 2014).

Behavioural change for sustainability means people should change their habits – how they dress, what they eat, how they travel, and how they relax. In this way, being more responsible for using the limited resources of the earth, some convenience must be sacrificed. The voluntary simplicity movement for example tries to redefine what a good life means, and two aspects of it are to reduce the quantity of consumption and purchase products that are good socially and ecologically (Chen et al. 2022). Win-win decisions are those which may become most popular (e.g. which provide financial savings or health benefits besides being good for the environment), but those are more challenging and cause both inconvenience and higher costs. For example, convincing people to eat meat alternatives should promise that the taste is very similar, but it is healthier, good for the animals and its production uses less water (Font-i-Furnols, 2023).

The self-concept on the one hand can reassure sustainable consumption by strengthening the positive feelings toward us, that we take care of others and respect them, but also people want to express themselves through what they have, and what they consume. Therefore, self-consistency has a relevant effect on the final behaviour (White et al. 2019). Feelings and cognition also play important roles in changing behaviour. Of course, education and sharing knowledge on different channels about environmental and social issues can form young adults' behaviour, but besides the cognitive way, also an effective way of convincing them can work. In this case, both positive and negative feelings can make a change. Different sources have already studied climate- or eco-anxiety (Kurth & Pikhala, 2022; Boluda-Verdú et al. 2022), which may result in stress, depression and a lack of hope for the future. Almost half of 10000 young people (aged 16-25) asked in 10 different countries say their feelings about climate change are negatively affecting their daily lives, and 77% say they face a scary future because of climate change, (Hickman et al. 2021).

If eco-anxiety is a practical anxiety, which means that a person is uncertain what the right thing to do and how to handle ecological challenges, then it results in questions like these: „Should I have a child given the risk that climate change poses to her future? Should I change my profession, or should I try to bring more environmental responsibility into the job that I have? Should I spend more time raising awareness

about climate change in my community—and should I do that even if it means spending less time with my family?" (Kurth & Pihkala, 2022, p.6.) Some personality traits like altruism have also been proven a good indicator of both environmentally correct purchase and resource-saving activities (Ribeiro et al. 2016).

The tangibility of the outcomes of sustainability behaviour is another aspect which would motivate people to change (White et al, 2019). Sometimes the results of these efforts cannot be measured or only may influence the environment in the long term, which makes it difficult to be supported by prompt actions now.

A sustainable lifestyle may mean different consumption (e.g. considering raw materials and ingredients) but also mean sacrifices by giving up things we have already gotten used to (e.g. convenience or cheap products). Considering what to give up, it is crucial to know what those fields in household consumption are which could significantly decrease the environmental impact of their behaviour. Spangenberg & Lorek (2002) mention that construction and housing, food and nutrition and transport and mobility are those areas which responsible for two-thirds of material extraction and energy consumption and 90 % of land use. Therefore, these are the areas where households and young people should revise their decisions.

Focusing on gender differences, former studies found significant gender differences in sustainable consumption behaviour, underlying that women show strong concern about the effects on their consumption decisions (Luchs & Mooradian, 2012; Wyrwa et al, 2023). A good example of the complex ecological footprint analysis of university students showed that students' ecological footprint was slightly lower than the national average and male students had significantly higher ecological footprint than female students (Medina & Toledo-Bruno, 2016).

3 Methodology

The Higher Education for Good Foundation (HE4G) created the Youth Talks (YT) Survey as a part of Principles for Responsible Management Education (PRME) which is a United Nations-supported initiative founded in 2007. HE4G specifically focuses on young people aged between 15-29. One segment of this worldwide extended study is a semi-structured interview round where 78 interviews were carried out and transcribed. The interviews conducted spanned approximately 15 to

20 minutes each and were carried out in diverse locations. YT tried to cover every region of the world. All interviews have been transcribed for thorough analysis. Access to the video interviews is available via the website, and the authors have permission to access the corresponding transcriptions. The transcriptions were explored with NVivo12.

Altogether 38 males, 39 females and 1 nonbinary interviewee participated from 12 countries (see Table 1.), whose average age was 23.8 years.

Table 1: Sample size by countries

Country	Number of respondents	Country	Number of respondents
Australia	6	Lebanon	6
Brazil	8	Morocco	6
China	6	Philippines	6
Finland	6	Romania	6
France	8	South Africa	6
Ivory Coast	6	USA	8
Total			**78**

Source: own elaboration

The interview guide contained chapters and in total of 11 question boxes, one question box was selected for this study. Participants were asked that "to build a desired future, what they would be ready to give up". Young people are faced with a dilemma, choosing between their present needs and their desires for a sustainable future. Their responses reflect this dilemma, as well.

The examination happened in two phases, firstly the auto-coding revealed the most frequently used expression and afterwards based on the synonyms a topic-relevant code book was automatically created.

4 Results

Firstly, the word cloud was created which shows the 50 frequently used (at least 3 letters long) words. Here stemmed words were merged, too.

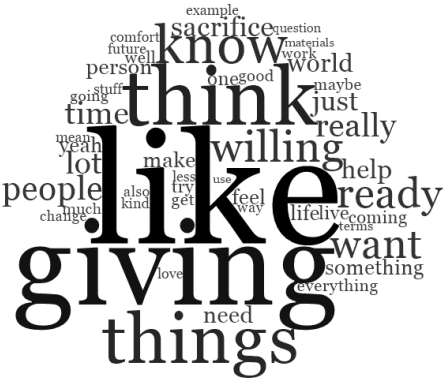

Figure 1: Word cloud
Source: own elaboration

As Figure 1 shows, mostly, linking words are listed. Only three relevant expressions can be discovered "*materials*", "*comfort*" and "*love*". That is why, we continued with topic-relevant auto coding where the synonyms were also handled and the entire sentences (i.e. the environment of an expression were also considered). The first version was pre-evaluated, and the separated but semantically close nodes have been merged. Table 2. provides a summary of relevant topics.

Table 2: Results of auto coding: code book with examples of what to give up

Name	Description
comfort	Subcodes: comfort zone; comfortable situation; comfortable things; extreme comfort
I think it's a comfort zone, as the name suggests, it's a place you stay in and it's comfortable. … So I would be ready, yes, to step out of my comfort zone so that everything can change and the wishes that I have for the future, the concerns that I have can really change and come true. (male, 22, Brazilian)	
life	Subcodes: day life; material life; personal life; real life; reasonable life; whole life
Actually facing my passion and real life, I'm ready to give up what I like. (male, 25, Chinese) *I would be ready to give up things, how to say... ways of living (female, 23 French)*	
material	Subcose: anything material; material things; fossil materials; material life; material stuff;
I would say anything material I would be ready to give up. (female, 29, Finnish) *I would also be willing to give up many other things, such as material things. (female, 26, Finnish)*	
meat	Subcodes: eating meat; meat consumption, overall consumption;
I could stop eating meat first of all, because we know it's a product. (male, 20, French)	
question	Subcodes: difficult question; great question; interesting question; tough question
So it's quite a tough question to say today, well, what am I ready to give up? (female, 28, French)	

Name	Description
It's a difficult question, I have to think about it. (female, 18, Brazilian)	
things	Subcodes: bad things, certain things, comfortable things; expensive things; external things; heavy things; important thing everyone; material things; obvious things; precious things; problematic thing; really things; several things; tangible things
I would also be willing to give up many other things, such as material things. (female, 26, Finnish)	
time	Subcodes: free time, full-time career, good times; leisure time; maybe time; personal time; spare time; tough time
I'm ready to give up my hobbies, my outings, the many things I do in my spare time I'm willing at the moment to give up most of my free time. (male, 18, Romanian) *So I would give up my free time. (female, 27, Romanian)*	
world	Subcodes: conservative world; global world; perfect world; progressive world; utopia world; world sake
Those are some of the things and privileges that, in my utopia world, would not be maintained. (female, 26, Finnish)	

Source: own elaboration

Firstly, the question code indicates that some interviewees were surprised to hear this question. Seemingly, they never thought that their generation should sacrifice anything for a better future. However as one of them said, "*I am part of a generation where we are already aware of certain things, I think.*" (male, 20, French)

A few of them state that they are not willing to give up anything ("*In order to achieve my hopes for the future, what would I be willing to give up? That's a tough one… I kind of feel like I have nothing to give, I've already given everything up. I realize that I'm at such a point in my life that I'm the priority. Oh my, I have to admit that I actually wouldn't give much up.*" (non-binary, 26, Finnish). or in a more precise way they do not have anything worthy to give up ("*You know, well, I have nothing. So to willing to give but I will put my energy, love and work. I'm willing to give all of it work, love and share it. (male, 19, Philippine.*) That is why a lot of them would sacrifice their free time ("*In terms of what I'm ready to give up to achieve what I hope for on a personal level — to achieve that freedom — I'm probably ready to give up for now some leisure time and certain extra or finer things so that I can work to be free at some point.*" – male, 27, Finnish).

Obviously, some material things were also mentioned ("*I think the tangible things that I have, that expensive things, all those anything, I think I would really give up anything for the world that I'm hoping for.*"- female, 21, Philippine). Surprisingly they are ready to change their food consumption habit, as well. (For example, *"And I think I'd be ready to give up, for example, eating meat, whereas I am a big carnivore, like a huge carnivore"* – female, 23, French)

Based on demographical background information, certain patterns can be also observed. More males (10 from 38) mentioned "*comfort*" and comfort zone than females (2 from 39). While, the girls seemed to have a broader perspective and referred to the "*world"* more ("*I think in terms of the, the broader world sake, I need to compost more.*" – female, 24, Australian). Even though, material things and free time were revealed by both genders. As for the national comparison, we found that meat consumption was declared mainly by French participants and almost all Romanian young people mentioned free time.

5 Discussion

As we are focusing here on young adults, we must emphasise that at this stage of their life – according to the life-cycle hypothesis – they have low income or do not have income, but may have student loans, some still live with their parents or in dormitories or with roommates from the money they get from their parents, which have a significant effect on what they consume, and therefore, what they can give up for a more sustainable future.

Aligning with the findings of AI-based analysis of PRME Youth Talks, we also proved that activities (travel, hobbies and passions), personal ambitions and material consumption (food, cars, technology, etc.), are what young people are willing to sacrifice. The latest also states the crucial importance of the UN Goals. According to the United Nations' Sustainable Development Goal (SDG) 12, it is necessary to change food production and consumption to be more sustainable (UN, 2022). Moreover, this is accepted by both genders. Recently, Barrera-Verdugo & Durán-Sandoval (2024) also examined the positive effect of moral reasoning and environmental concern on sustainable food consumption among university students, and they found that the influence of moral reasoning on food consumption did not differ by gender.

However, some participants clarified items that they would never give up, but the interview guide contained a specific question about things that they would never give up. ("*The things that I won't sacrifice for this world are my friends, my family and people that I love, even if my own perfect world can't exist, I can't lose them*"- female, 20, Libanonese). Mainly their relationships were that they refused to sacrifice for the future.

6 Conclusions

This paper aims to understand the dilemma these young people face between the needs of the present and the aspirations for a sustainable future. The complexity of their responses reveals disagreements, reflecting the challenges between personal goals and collective needs. The sacrifices described by young people reflect a rising awareness of global issues and a willingness to take action for the common good. They are ready to give up the most important resource that they own at their age which is free time.

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"All intellectual property rights in the data used in this work are the sole property of the Higher Education for Good Foundation. The author(s) alone is/are responsible for the views, positions or policies expressed in this work and they do not necessarily represent those of the Higher Education for Good Foundation."

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Cost Optimization Through Quality Management for a Sustainable IT Company

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Numerous studies support the notion that quality management plays a crucial role in enhancing economic efficiency, particularly through cost reduction and the optimization of operational processes. Companies operating in the IT sector typically focus on compliance with the ISO 27001 and ISO 20000 management systems. Additionally, in recent years, the emergence of frameworks such as NIS 2, DORA, and ESG has introduced new challenges for industry stakeholders. It is also essential to mention ITIL, which serves as the repository of "best practices," as the proper implementation of this system significantly influences the efficiency and quality of IT services. The aim of this publication is to compare and examine the requirements of the standards and frameworks, assessing their impact on cost reduction and efficiency improvement in quality management, as well as their effects on the sustainability of management systems. The risks and opportunities associated with these frameworks are analyzed using secondary research, answering my research questions through the review of relevant academic literature. The expected findings of this research suggest that integrating these new regulations and frameworks into corporate strategy not only facilitates legal compliance but also contributes to cost reduction and process efficiency improvement in the long term.

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1 Introduction

In the modern business world, cybersecurity and the associated improvement of service quality play an increasingly significant role in the operations of IT companies as well. For larger enterprises, the implementation and adherence to standards such as ISO 27001 and ISO 20000 are not uncommon. In 2022, a new edition of the ISO 27001 standard (ISO/IEC 27001:2022, 2022) was released, introducing a completely revised annex and numerous new compliance requirements. Beside that, a growing proportion of IT companies utilize the ITIL (Information Technology Infrastructure Library) framework, which is closely linked to the ISO 20000 standard (ISO/IEC 20000-1:2018, 2018) family (Arraj, 2010). However, the development of cybersecurity and the establishment, support, and enhancement of IT service management alone do not necessarily guarantee the effective operation of quality management. As a result, untapped efficiency reserves may exist within the company's operations.

New European Union regulations have imposed additional obligations on these companies. IT service providers as third party to banking clients affected by the Digital Operational Resilience Act (DORA) (REGULATION (EU) 2022/2554 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, 2022). Over the past decades, the application of information and communication technologies (ICT) has played a pivotal role in financial services, to the extent that it has become indispensable to the daily operations of financial institutions. In parallel, NIS2 regulations have been released by the European Union, which requires strengthening the cybersecurity of the member states (DIRECTIVE (EU) 2022/2555 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL, 2022). With that, the government is going to control and monitor such activities, which means high focus at IT companies to fulfill the requirements.

Beyond regulatory requirements, the Environmental, Social, and Governance (ESG) framework has also emerged as a key consideration. The integration of ESG principles into the IT industry is not only important from ethical and legal perspectives but also offers a competitive advantage (Armstrong & McLaren, 2022).

To summarize my key research questions, I am looking for risk and opportunities for the following:

1. How does the integration of ISO 27001 and ISO 20000 enhance IT service quality and cybersecurity resilience?
2. In what ways does compliance with evolving regulations such as DORA and NIS2 increase operational complexity while improving risk management in IT companies?
3. How do organizations that align IT service management with ESG principles gain a competitive advantage and improve stakeholder trust?

2 Theoretical Background

The foundation of every management system comes from the need for quality. Basically, quality management focuses on profit orientation, therefore cost optimization is key for success. The concept of quality costing was first introduced by Juran (1951) in his Quality Control Handbook, where he defined quality costs as "the costs which would disappear if no defects were produced" (Juran, 1951). The challenge lies in determining the optimal quality level that minimizes the total cost of quality (Schiffauerova and Thomson, 2006). Sturm, Kaiser, and Hartmann (2019) explore the long-term relationship between cost of quality and quality performance, emphasizing the importance of sustained investment in quality management to reduce costs over time. Similarly, Fok, Fok, and Hartman (2001) analyzed the role of Total Quality Management (TQM) in information systems development, demonstrating that TQM principles enhance IT efficiency and effectiveness.

In the IT industry, the P-A-F model could be a highly useful tool, comprising the elements of prevention, appraisal, and failure analysis. Vakilifard and Khozein (2012) analyze the four major cost categories in quality management.

These principles led to more complex IT specific requirements; the ISO 27001 standard. While ISO/IEC 27001 and ISO 9001 (ISO 9001:2015, 2015) serve distinct purposes, they can work together to enhance organizational performance. This integration fosters trust, strengthens resilience, and enhances competitive positioning in the market. (Hyseni, 2025)

With the improving cybersecurity and data privacy, new regulations released by the European Union. Firstly the DORA (Digital Operational Resilience Act) came into effect which affects the third party ICT suppliers of the banking sector (2022). This act is determined to have disaster recovery planning and business impact analysis, therefore it is a kind of combined version of ISO 27001 and ISO22301 standards. Beside that, NIS2 (Network and Information System) EU directive was released which requires developing the capability of cybersecurity resilience of each member state. This directive has a similar approach to the quality management system regarding the senior management accountability and the top-down approach. (2022) In addition, it requires the establishment of a Cybersecurity Incident Response Team to manage all the upcoming issues and risks, which eventually increases the overall IT controls.

For further support to improve the service level quality, ITIL (IT Infrastructure Library) and ISO 20000 can provide the proper guidance. ITIL and ISO 20000 are key frameworks in IT service management (ITSM). ITIL standardizes IT service processes, improving efficiency and adaptability across industries (Arraj, 2010; Cervone, 2008). ISO 20000 builds on ITIL principles, offering a structured certification process for compliance and quality assurance. Sahibudin, Sharifi, and Ayat (2008) highlight the integration of ISO 20000 with ITIL, COBIT, and ISO/IEC 27001 for a robust IT governance framework. ITIL's flexibility allows organizations to tailor IT service management strategies, while ISO 20000 ensures accountability and consistency. Popli and Chauhan (2014) emphasize aligning ITSM with agile methodologies to enhance service delivery. Combining both frameworks enhances operational efficiency, regulatory compliance, and service quality.

To achieve the optimized process efficiency and sustainability, IT companies are key players in global net-zero transitions. They are required to have strategies to reduce carbon footprints (Armstrong & McLaren, 2022). Markard and Rosenbloom (2022) outline various phases of the net-zero transition, emphasizing the importance of policy frameworks and technological innovation in achieving sustainability. Furthermore, Environmental, Social, and Governance (ESG) considerations are becoming increasingly significant in the IT sector, influencing corporate sustainability strategies. Organizations are implementing energy-efficient data centers, responsible e-waste management, and ethical AI development to align with ESG principles. ESG in IT is a critical factor in achieving sustainability goals. By

integrating net- zero strategies and responsible IT practices, organizations can enhance environmental responsibility while fostering long-term business resilience.

To encapsulate the core of my research inquiries, this study aims to identify and analyze the associated risks and opportunities pertaining to the following questions:

- How does the integration of ISO 27001 and ISO 20000 enhance IT service quality and cybersecurity resilience?
- In what ways does compliance with evolving regulations such as DORA and NIS2 increase operational complexity while improving risk management in IT companies?
- How do organizations that align IT service management with ESG principles gain a competitive advantage and improve stakeholder trust?

3 Methodology and Results

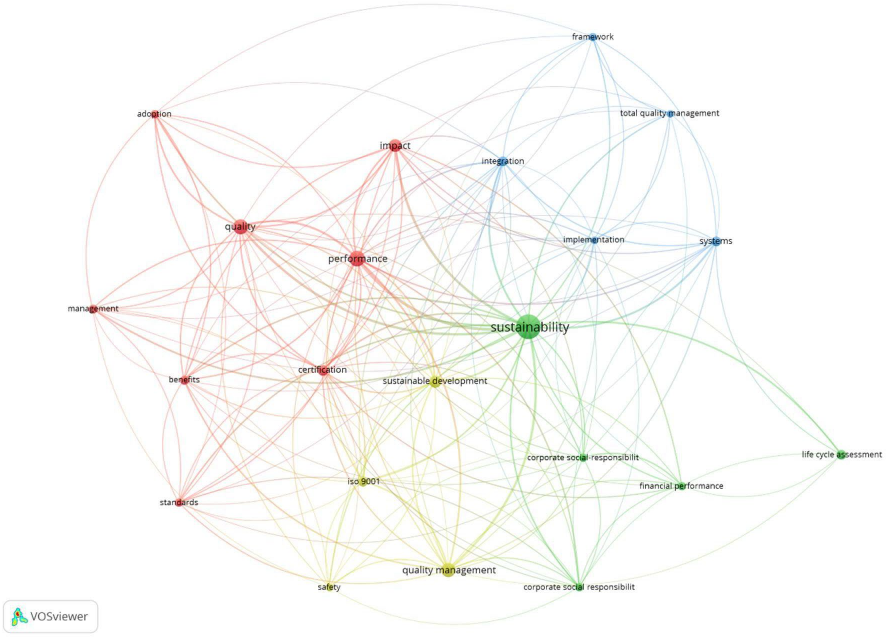

Figure 1: A heatmap - VOSviewer

To prepare the topic of the conference paper by secondary research, I used to collect all the necessary keywords to build a comprehensive search query through the Web of Science. After the search query launched, I collected and stacked the full articles with Notepad++. To filter the relevant topics, I used that stacked file in VOSviewer to create a heatmap with the keywords as showed on figure 1. Eventually, I started to process scientific articles based on my narrowed research area.

To start with, the intersection of quality management, IT service frameworks, cybersecurity regulations, and ESG considerations presents both risks and opportunities which provides answers for the research questions.

As the key risk, optimizing quality while controlling costs is challenging; underinvestment leads to defects, while overinvestment may not be cost-effective (Schiffauerova & Thomson, 2006; Sturm et al., 2019). Poor prevention efforts result in costly internal and external failures (Vakili Fard & Khozein, 2012), increasing cybersecurity threats and reputational damage. Adapting to evolving frameworks like DORA and NIS2 while aligning ISO 9001 and ISO/IEC 27001 poses operational challenges (Hyseni, 2025). Integrating ITIL and ISO 20000 requires balancing flexibility with compliance (Sahibuddin et al., 2008; Popli & Chauhan, 2014).

On the opportunities side, TQM and structured ITSM lower long-term costs and enhance efficiency (Fok et al., 2001; Sturm et al., 2019). Combining ISO 20000, ITIL, and cybersecurity frameworks improves compliance and risk management (Sahibuddin et al., 2008). Net-zero initiatives and responsible IT practices boost corporate reputation and resilience (Armstrong & McLaren, 2022; Markard & Rosenbloom, 2022). Standardized ITSM enhances reliability and customer trust, while agile integration increases adaptability (Arraj, 2010; Cervone, 2008; Popli & Chauhan, 2014).

4 Discussion

The findings suggest that IT organizations must adopt a proactive approach to quality management by integrating ITSM frameworks, cybersecurity standards, and regulatory compliance. The interplay between ITIL, ISO 20000, and ISO 27001 presents a unique opportunity for companies to establish a comprehensive quality management system at a sustainable IT company. However, the challenge lies in

balancing flexibility with compliance, especially in rapidly evolving regulatory landscapes such as DORA and NIS2. ESG considerations further complicate IT quality management, requiring organizations to align sustainability goals with operational efficiency.

Moreover, organizations must recognize the significance of a risk-based approach when implementing and maintaining a quality management framework in parallel with other IT specific systems. Therefore, companies must develop adaptive compliance strategies that address emerging threats while maintaining operational resilience. Additionally, the alignment of ITSM with ESG policies requires organizations to incorporate sustainability metrics into their performance assessments, ensuring that environmental and social responsibilities are integrated into IT operations.

Ultimately, secondary research highlights the necessity of a holistic approach to IT quality management, where regulatory compliance, cybersecurity, and sustainability are interwoven into a single strategic vision. Organizations that successfully navigate this complex landscape will be better positioned to foster innovation, enhance customer trust, and sustain long-term growth.

5 Conclusions

The research conducted provides valuable insights into the integration of ISO 27001 and ISO 20000, compliance with evolving regulations such as DORA and NIS2, and the alignment of IT service management with ESG principles.

Firstly, the integration of ISO 27001 and ISO 20000 significantly enhances IT service quality and cybersecurity resilience. By combining these standards, organizations can establish a robust framework that ensures the protection of information assets while maintaining high service quality. This integration promotes trust, strengthens resilience, and enhances competitive positioning in the market.

Secondly, compliance with evolving regulations such as DORA and NIS2 increases operational complexity but also improves risk management in IT companies. The Digital Operational Resilience Act (DORA) and the Network and Information System (NIS2) directive require organizations to develop comprehensive disaster

recovery plans, business impact analysis, and cybersecurity resilience capabilities. These regulations necessitate a top-down approach to quality management, ensuring senior management accountability and the establishment of a Cybersecurity Incident Response Team to manage risks effectively.

Lastly, organizations that align IT service management with ESG principles gain a competitive advantage and improve stakeholder trust. The integration of Environmental, Social, and Governance (ESG) considerations into IT operations is crucial for achieving sustainability goals. By implementing energy-efficient data centers, responsible e-waste management, and ethical AI development, organizations can enhance their environmental responsibility while fostering long-term business resilience.

Despite the valuable insights provided, this research has several limitations. Firstly, the study relies heavily on secondary data, which may not capture the most recent developments in the field. Additionally, the research focuses primarily on large enterprises, potentially overlooking the unique challenges faced by smaller IT companies. The study also assumes a uniform environmental impact. Moreover, IT firms must integrate ESG considerations into their supply chains, ensuring ethical sourcing of materials, reducing emissions from cloud and data center operations, and enhancing circular economy principles. The adoption of renewable energy in IT infrastructure, alongside energy-efficient data centers, plays a crucial role in achieving Net Zero ambitions while maintaining cost-effective IT services.

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Evaluating the Effectiveness of EU Sanctions On Russian Financial Markets: A GARCH-Based Approach

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This study assesses the efficiency of European Union sanctions imposed on Russia in 2022–2023, focusing on their short- and mid-term impact on financial markets. Despite Russia's restrictions on macroeconomic and international trade statistics, stock market data remains accessible, allowing an empirical investigation of market responses. Using a CCC-GARCH model, particularly conditional covariance estimation, the study analyzes volatility spillovers and contagion effects across Russian financial markets: stock, government bond, and foreign exchange markets. The findings identify key turbulence periods and the "first domino knuckle"—the initial markets most affected—shedding light on market resilience and shock transmission. Since all the sanctions remain in place and new ones continue to be imposed, assessing their long-term effects is not yet possible. However, this study could provide valuable insights on the effectiveness of economic sanctions and contribute to the broader discourse on economic coercion and market stability.

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1 Introduction

The Russian economy remains under stringent international sanctions. The European Union, Russia's primary trading partner until 2022, has led these efforts. While the sanctions have not achieved their stated objectives, they have inflicted some economic damage. Three years after their implementation, debate persists over their effectiveness, with arguments for both tightening and easing certain restrictions as tools of coercion or incentive. In this context, all parties must assess which existing sanctions have had the most significant impact on the Russian economy.

Since 2022, Russia has significantly restricted access to official macroeconomic and foreign trade statistics, complicating the assessment of sanctions' impact (Chernykh, 2024a). However, aside from a one-month suspension in 2022, the stock market and its indices continue to provide publicly available exchange-traded data for evaluating sanctions' effectiveness.

The stock market, particularly stock indices, has traditionally served as a tool for assessing the impact of negative events such as epidemics, trade wars, and sanctions on an economy. Beyond analyzing changes in returns, a common approach is to evaluate risk or uncertainty. In the scientific literature, uncertainty is typically measured by volatility, which serves as a proxy for the national financial market's condition during crises and as an indicator of country risk (Aganin, 2020).

This paper aims to evaluate the effectiveness of economic sanctions imposed on Russia by the European Union from 2022 to 2023 by analyzing volatility spillovers and contagion effects across different segments of the Russian stock market. Since the long-term impact of sanctions depends on both economic factors and geopolitical developments—such as the potential imposition or removal of sanctions in anticipation of peace negotiations—this study focuses on their short- and mid-term effects.

The paper is structured as follows. Following the introduction, which includes the study's motivation and a brief review of relevant research, the next section presents the methodology. This is followed by a description of the data. The paper concludes with a summary of findings.

2 Literature review

Second-moment analysis enables the estimation of market contagion effects, defined as excessive cross-country correlation during crises (Beirne et al., 2013), such as sanction periods. The generalized autoregressive conditional heteroskedasticity (GARCH) family of models provides a framework for estimating contagion effects and identifying abnormal volatility shifts during market turbulence.

Various GARCH model variations have been extensively used to assess the impact of sanctions. Economic sanctions on Iran have been analyzed using MGARCH to examine the relationship between the exchange rate, oil prices, and Iranian exports (Omidi et al., 2021). Research on the Russian stock market employed GARCH models even before sanctions were imposed; for instance, contagion effects between the U.S. and Russian stock markets were estimated using VAR-GARCH for the period 2005–2013 (Syriopoulos et al., 2015). Regarding the 2014–2021 sanctions against Russia, Afanasyev et al. (2021) applied an ARMAX-GARCH model to assess the impact of tweets on the ruble exchange rate. TGARCH (Aganin, 2021) and EGARCH (Sultonov, 2020) models have been used to analyze the relationship between the volatility of the Russian stock index and oil prices. Fedorova et al. (2024) also include 2022-2023 sanctions in their sample when estimating the volatility of Russian sectoral indices and news background using GARCH model.

The sanctions imposed on Russia since 2022 have several distinctive features that must be considered in model development. Beyond the restricted access to foreign trade data, these include the non-transparent pricing of Russian oil and oil products (Vakulenko, 2023), sanctions on public debt, and the simultaneous targeting of exports, national reserves, and imports. This pressure can generate opposing effects, which the national currency may absorb (Itskhoki & Mukhin, 2022).

This necessitates excluding foreign trade indicators and oil prices from the volatility estimation. Instead, the ruble exchange rate and the government bond market, as key financial variables, are incorporated into the model. Accordingly, this study examines the interactions among three financial variables in Russia: the stock market, the government bond market, and the ruble exchange rate.

3 Methodology

Among the GARCH models discussed, the VAR-GARCH model warrants particular attention. The choice of VAR is motivated by potential interdependencies among index returns, as financial returns often exhibit cross-correlations. Implementing VAR first eliminates autocorrelations before applying GARCH. Once dependencies are removed, the residuals exhibit volatility clustering but no strong serial correlation.

The return equation for the trivariate model follows a VAR(1) process:

$$R_t = C + \Phi R_{(t-1)} + \varepsilon_t \quad (1)$$

where:

R_t – a vector of returns for three financial variables: equity market, bond market, and foreign exchange market: $R_t = (r_t^m, r_t^f, r_t^c)'$, C – a constant vector, Φ – a (3x3) matrix of VAR(1) coefficients φ^i capturing the linear dependencies. $\varepsilon_t = (\varepsilon_t^m, \varepsilon_t^f, \varepsilon_t^c)'$ – residuals (innovations), modeled with a GARCH process. The equation for the residuals is given by:

$$\varepsilon_t = H_t^{(1/2)} z_t \quad (2)$$

where:

$H_t^{(1/2)}$ – a symmetric positive definite matrix, the square root of the conditional covariance matrix H_t, z_t – a vector of i.i.d. standard normal shocks, i.e. $z_t N(0, I_3)$

One of the most widely used specifications for modeling the matrix H_t is the full BEKK-GARCH model (Engle & Kroner, 1995). However, with two return series, optimizing eight parameters can complicate calculations and lead to biased estimates (Aganin & Peresetsky, 2018). A similar issue arises when estimating the parameters of the VAR-GARCH model (Ling & McAleer, 2003). The constant conditional correlation (CCC) specification requires estimating ten parameters, whereas the bivariate CCC-GARCH model (Bollerslev, 1990) requires only six. According to

Arouri et al. (2015), the CCC-GARCH model produces comparable results in modeling the conditional volatility of financial index returns.

The matrix H_t in the bivariate CCC-GARCH model for each pair of indices is calculated as follows:

$$H_t = D_t P D_t \tag{3}$$

where:

D_t – a matrix defined by equation:

$$D_t = diag\left(\sqrt{h_t^i}\sqrt{h_t^j}\right) \tag{4}$$

P – a constant correlation matrix:

$$P = \begin{bmatrix} 1 & \rho_{(i,j)} \\ \rho_{(i,j)} & 1 \end{bmatrix} \tag{5}$$

Conditional variances from the matrix D_t for each of the two financial variables are determined by the following equation:

$$h_t^i = \omega_i + \alpha_i\left(\varepsilon_{(t-1)}^i\right)^2 + \beta_i h_{(t-1)}^i \tag{6}$$

where:

ω – a long-term volatility component, α – impact of past squared shocks, β – persistence of volatility. All parameters should be non-negative. The sum $(\alpha + \beta)$ reflects the speed with which negative effects disappear over time. If the data take on higher values over time, for example, during periods of significant sanctions, this indicates a higher level of risk in the studied markets.

Conditional covariance of two variables is calculated as follows:

$$h_t^{(i,j)} = \rho\sqrt{h_t^i h_t^j} \tag{7}$$

where:

ρ – a constant conditional correlation coefficient.

This study hypothesizes that during periods of heightened turbulence—marked by the imposition of major economic sanctions—abnormal conditional covariance will indicate contagion between markets.

4 Data

The sanctions include both broad economic measures and reputational penalties targeting individuals or industries with minimal economic significance in Russia, such as the luxury goods sector. Research on the previous wave of anti-Russian sanctions (2014–2021) suggests that the oil and gas industry was the most affected (Vladimirov, 2017; Zaytsev & Loshchenkova, 2023). Accordingly, this study focuses on Russian oil and gas stocks, selecting companies listed in the Moscow Exchange Oil & Gas Sectoral Index (MOEXOG) as a representative sample of this key sector.

As a financial variable representing the government bond market, this study uses the Moscow Exchange Government Bond Index (RGBITR), which measures the performance of the Russian sovereign debt market (Moscow Stock Exchange, 2025). The official exchange rate of the Russian ruble to the US dollar, provided by the Central Bank of Russia, represents the currency market. All three financial variables are analyzed as logarithmic returns.

Stationarity is tested using the Augmented Dickey-Fuller and Phillips-Perron tests. The study relies on daily observations, with missing data leading to the removal of the entire observation across all variables. The sample covers 2020–2023, with observations for 2022 beginning on March 28 due to trading restrictions in February–March.

Regressions are estimated separately for each year to account for distinct geopolitical events in the sample, including the COVID-19 pandemic, the 2022 escalation of the armed conflict in Ukraine, and the imposition of full-scale sanctions. This annual segmentation facilitates a comparison of pre- and post-sanctions periods to assess changes in volatility dynamics and aligns with the hypothesis of constant conditional correlation.

The study focuses on economic sanctions that demonstrated significance in event analysis, identified by abnormal returns during the event window—specifically, the announcement or imposition of sanctions (Chernykh, 2024b).

Table 1: List of sanctions events imposed by the EU on Russia's oil and gas industry.

	Announcement date	Event description
(1)	03 June, 2022	6th package: imposition of sanctions
(2)	02 September, 2022	8th package: announcement of the oil price ceiling
(3)	06 October, 2022	8th package: imposition of sanctions
(4)	04 February, 2023	8th package: setting of the price ceiling for Russian oil products
(5)	23 June, 2023	11th package: ban on servicing Russian oil tankers in third countries

Source: Bown, 2023.

The sample excludes the initial sanctions imposed in February–early March 2022 for the following reasons: (1) stock exchange closures during this period and (2) the overlap of sanctions-related and military events.

5 Results

The results of equations (1) and (6) are presented in Table 2. The VAR(1) return equations exhibit the following temporal dynamics:

- The equity market developed a significant autoregressive component in 2022 and a positive mean in 2023, indicating a sustained growth phase, reflecting adaptation to sanctions.
- The bond market returned to medium-term growth in 2023 after experiencing a sustained negative mean in 2022, which, in absolute terms, exceeded that of the COVID-19 period. Autoregressive dependence was present throughout the entire observation period.

– The ruble exchange rate reversed its dependence on stock market returns with the onset of full-scale sanctions, shifting to co-movement. This suggests that stock index growth was offset by a depreciation of the national currency and vice versa. Additionally, in 2022, the ruble exhibited a significant positive autoregressive component, which disappeared in 2023.

Table 2: The result of equations (1), and (6)

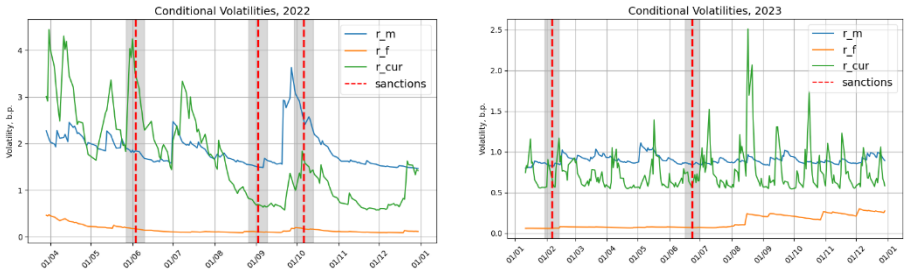
	MOEXOG				RGBITR				USD/RUB			
Year	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021	2022	2023
Obs.	232	241	189	245	232	241	189	245	232	241	189	245
Results for mean equation R_t VAR(1)												
c	-0.034 (-0.275)	0.0196 (0.242)	-0.116 (-0.790)	0.165 (2.762) ***	-0.011 (-2.008) **	0.012 (3.131) ***	-0.039 (-2.487) **	0.017 (1.662) *	0.113 (1.768) *	-0.021 (-0.613)	-0.018 (-0.131)	0.047 (0.908)
φ^m	0.071 (0.967)	0.067 (1.027)	0.166 (2.280) **	0.190 (3.013) ***	-0.008 (-2.396) **	-0.0005 (-0.184)	0.0021 (0.286)	0.0059 (0.553)	-0.129 (-3.342) ***	-0.075 (-2.676) ***	0.0742 (1.083)	0.126 (2.330) **
φ^f	0.666 (0.387)	1.015 (0.733)	-1.172 (-1.602)	-0.637 (-1.655) *	-0.055 (-0.738) **	0.230 (3.620) ***	0.208 (2.701) ***	0.137 (2.110) **	1.649 (1.829) *	1.489 (2.499) **	0.464 (0.672)	0.079 (0.240)
φ^c	-0.335 (-2.711) ***	0.155 (1.059)	-0.086 (-1.088)	-0.048 (-0.626)	0.013 (2.470) **	-0.007 (-0.983)	0.006 (0.713)	0.0139 (1.088)	0.086 (0.186)	-0.076 (-1.213)	0.249 (3.334) ***	0.098 (1.499)
$f_\theta(x)$	-486.3	-205.9	-733.3	-487.1	-486.3	-205.9	-733.3	-487.1	-486.3	-205.9	-733.3	-487.1
Results for variance equation H_t CCC-GARCH(1,1)												
ω	0.1224 (1.801) *	0.0522 (0.998)	0.1919 (0.753)	0.1438 (0.779)	0.0002 (0.578)	0.0001 (1.515)	0.001 (2.071) **	0.0001 (0.169)	0.0977 (2.133) **	0.0297 (1.268)	0.0326 (1.260)	0.1729 (3.184) ***
α	0.1210 (2.689) ***	0.0350 (1.527)	0.0575 (1.697) *	0.0477 (0.649)	0.3345 (0.850)	0.0884 (1.980) **	0.0877 (1.064)	0.0301 (0.388)	0.0990 (1.847) *	0.0951 (1.352)	0.1702 (2.843) ***	0.3318 (2.297) **
β	0.8409 (20.58) ***	0.9291 (21.30) ***	0.8848 (20.72) ***	0.7763 (2.79) ***	0.6655 (1.781) *	0.8752 (13.79) ***	0.8438 (11.37) ***	0.9699 (6.343) ***	0.7910 (11.53) ***	0.7944 (6.861) ***	0.8298 (17.57) ***	0.4134 (3.816) ***
$f_\theta(x)$	-436.5	-383.1	-386.5	-320.7	337.5	372.130	101.2	161.8	-301.5	-178.2	-341.6	-266.6

Notes: t-statistics in parenthesis. *,**,*** denote rejection of the null hypothesis at the 10%, 5%, and 1% levels, respectively

The results in Table 2 for the conditional variance equation indicate that equity market volatility parameters declined by 2023. The immediate impact of past shocks was significant only during the COVID-19 period, while the long-run response decreased to minimal levels. In contrast, the bond market exhibited an extended duration of shock impacts, with β coefficients peaking in 2023. A significant long-term volatility component was also present in 2022, suggesting persistent volatility

following the onset of sanctions. The ruble exchange rate, similar to the equity market, exhibited a decreasing long-term memory for volatility over time but became more sensitive to immediate shocks. In 2023, the foreign exchange market also experienced sustained high average volatility (0.173).

Figure 1 illustrates the conditional variance for the two sanctions years for all of the markets.



(1) (2)

Figure 1: Conditional volatilities of the three indices estimated using equation (6).

A notable change in scale is evident: in the first sanctions year, volatility spikes exceeded 4 basis points (Fig. 1.1), whereas in 2023, only the ruble exchange rate reached 2.5 basis points (Fig. 1.2). Additionally, a general downward trend in conditional variance is observed. Regarding sanctions events, the ruble exchange rate exhibited increased risk in response to the first and third sanctions events from Table 1. The stock market showed a minor reaction to the second sanctions event. A notable spike in equity market volatility occurred before the third event window; however, this was unrelated to sanctions and instead coincided with the Ukrainian military counteroffensive in September–October 2022 (Fig. 1.1).

Figure 2 illustrates the conditional covariances for each pair of indices, enabling the analysis of contagion effects between financial markets during the first two sanctions years.

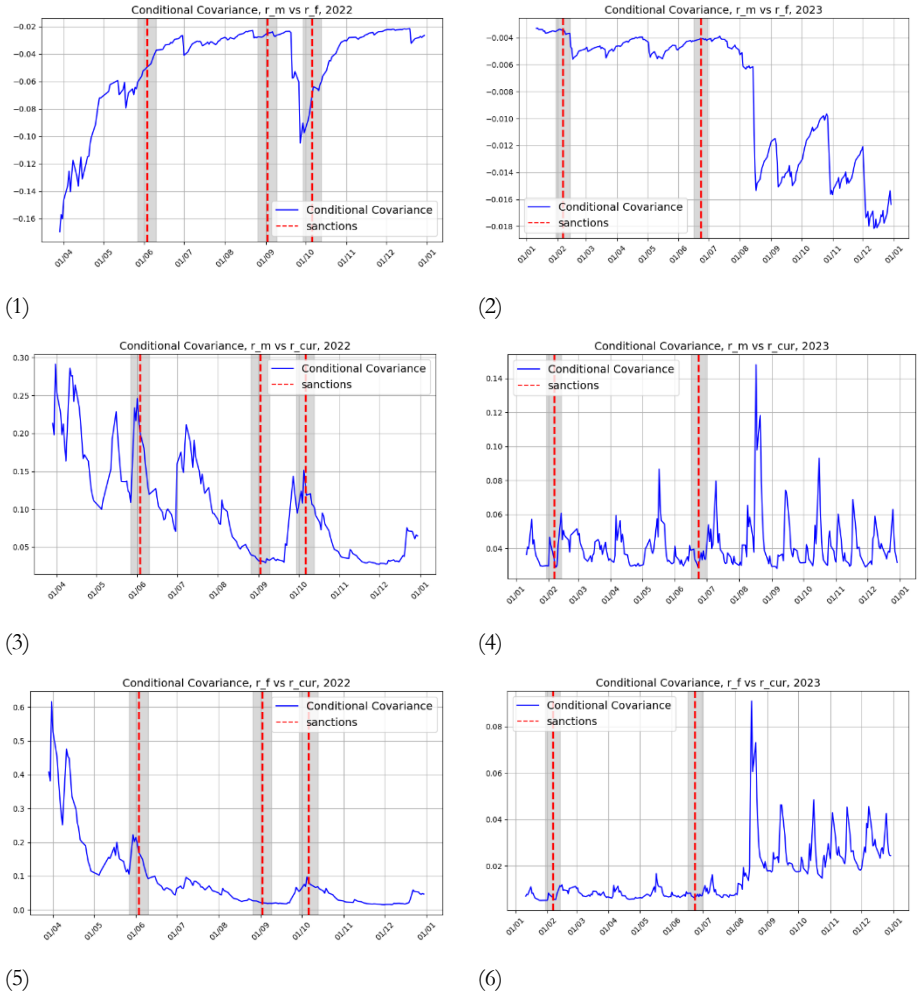


Figure 2: Conditional covariances for each index pair estimated using equation (7).

The negative correlation between the stock and bond markets (Figs. 2.1–2.2) reflects their differing risk profiles: risk-free government bonds versus the riskier stock market. Notably, volatility linkages strengthened during the fourth sanctions event (Fig. 2.2) but weakened during the first event window.

For the stock market and the ruble exchange rate, volatility linkages intensified during the first, third, and fourth event windows (Figs. 2.3–2.4). The bond and currency markets exhibited an identical reaction to these events (Figs. 2.5–2.6).

6 Conclusions

This paper analyzed three segments of the Russian financial market: the stock market, represented by the oil and gas index, the government bond market, and the foreign exchange market. The returns of these indices were examined using a VAR model before and after the imposition of EU sanctions. The residuals from these regressions were estimated using CCC-GARCH(1,1) models to identify contagion effects between markets. The introduction of the sixth and eighth package of sanctions resulted in excess volatility of the ruble exchange rate, transmitted also to stock and bond indices. The imposition of a price cap on Russian oil products also led to moderate increase in volatility in the equity market. By the second year of sanctions, the Russian oil and gas equity market had adapted by reducing risk perception indicators, whereas the government bond market exhibited a stronger long-term reaction to shocks. Overall, events unrelated to sanctions had a greater impact on Russian financial markets than the announcement or implementation of EU sanctions.

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The Influence of Ideology on Innovation as Manifesting Imagination: The Case of TESCREAL and AGI

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In this paper, we introduce an extended version of the concept of innovation as manifesting imagination. In the original concept, imagination has a key role in the preparation, diffusion and success of innovations. Now, we are integrating ideology and illustrating how it acts as a filter: Ideology not only defines what is desirable and what is not, as a complexity-reducing filter it also enables the argumentative reduction of future expectations by focusing on a specific narrative. We propose that the preferable futures that key entities like imaginators recognize, factor in and push are not purely economic in nature but driven by a rather rigid system of beliefs, imaginations, ideals and expectations, an ideology. While research has pointed to the role of institutions as well as the role of internal dynamics in shaping (organizational) behaviors, the role of ideology has been relatively neglected. Presenting the case of TESCREAL and AGI we are shifting the focus from media and the role of social entities to shared systems of believe, the combination of imaginations and ideals. Finally, implications for the formulation of alternative tech visions and strategies are discussed, especially with regards to sustainable development.

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1 Introduction

"We wanted flying cars, instead we got 140 characters." Peter Thiel

Concepts of innovation processes are frequently framed as starting with a problem to solve or an idea to be realized. But is that really the case? What about expectations of future developments, socially shared desirable, preferable and dystopian visions of the future? Maybe there is more to the success of innovation than just finding and applying a solution or realizing a specific idea or wish. Where are these ideas to be realized and the solutions stemming from? Which role does the social imagination play in this process and what influences it? Bucher (2019) and Bucher and Hüsig (2024) introduced the concept of innovation as manifesting imagination arguing that imagination has a key role in the preparation, diffusion and success of innovations. They have highlighted the roles of sedimented social imagination as well as specific social entities in this process. Science Fiction has been conceptualized as a medium that discusses, develops and diffuses concepts of the future of a certain period in time. It has been used to illustrate how concepts and expectations of the future are developed and diffused, preparing markets for future innovation, creating desires and priming future customers (Michaud 2017, Bucher 2019, Michaud and Appio 2022, Bucher and Hüsig 2024, Appio et al 2025).

Wernher von Braun and Elon Musk were presented as entrepreneurial "imaginators", social entities (in this case individuals) that use multi-modal representations of the future to promote and frame a set of scenarios of the future in which they define a desirable one to pursue – in order to realize a certain future goal on their own, such as their shared vision of a Mars project (Bucher and Hüsig 2024).

"I am enough of the artist to draw freely upon my imagination. Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world" Albert Einstein

2 Objective / Theoretical Background / Literature review

In this paper, we introduce an extended version of the concept of innovation as manifesting imagination, integrating ideology and illustrating how it acts as a filter: Ideology not only defines what is desirable and what is not, as a complexity-reducing

filter it also enables the argumentative reduction of future expectations by focusing on a specific narrative. Ideology as a filter allows for social alignment, frames futures scenarios and highlight key aspects within these futures (inherently muting alternatives). Historically, economic and technological development have been related to forces such as religion (Weber 2014 (1904), Merton 1938). Later social and economic welfare had been identified as a driving force of innovation (e.g. Rudolf Diesel's "Solidarismus", 1903 as one of the early proponents in which an engine was envisioned to free the people and lift them up to higher levels of prosperity). However, we propose that the preferable futures that key entities like imaginators recognize, factor in and push are not purely economic in nature but driven by a rather rigid system of beliefs, incorporating imaginations, ideals and expectations, an ideology. While research has pointed to the role of institutions as well as the role of internal dynamics in shaping (organizational) behaviors, the role of ideology has been relatively neglected (Foss and Klein 2024). It is easy to forget ideology in a "postideological" society when there actually is no space free of ideology (Žižek 1989, 1994). Ricoeur (1991) holds that the imagination often "operates as an 'ideology'" (Ricoeur 1991, p. 475) and thus not only creates the elementary symbolic structure of society but also continuously reaffirms and reinforces it through ideology.

Looking at the spectrum of competing concepts of the future, we were wondering why certain futures and future technologies are more prominent, reiterated and evolved than others. Therefore, we propose the following research question:

What is filtering the concepts and expectations of the future and setting what is preferable and undesirable, possible or preposterous?

Presenting the case (Eisenhardt 1989, Yin 2013) of TESCREAL we're shifting the focus from media and the role of social entities to shared systems of belief, ideologies, in order to get a better understanding of the process of imagination manifesting as innovation. Ideology is defined as a system of beliefs, a specific combination of imaginations, ideals, and expectations. TESCREAL is presented as a techno-optimistic ideology that combines the concepts of Transhumanism, Extropianism, Singularitarianism, Cosmism, Rationalism, Effective Altruism and Longtermism.

As theoretical lens we're using the futures cone by Gall et al. (2022) to discuss how ideology influences what we perceive and interpret as a preposterous, possible, plausible or probable future, not merely which future is preferred.

In the context of future and scenario planning, it is argued, that reimagining the future and with it, shifting ideals and expectations of the future and establishing novel ideologies are key to overcome the so-called "Clarke-Dator Boundary", the porous boundary between what are deemed possible and preposterous futures (Gall et al 2022, Candy 2010).

TESCREAL as an ideology and object of discourse is used to illustrate that the classification and interpretation of future scenarios are based on ideals, expectations and imaginations that aren't separate, unrelated factors but form a more or less cohesive, rigid system of beliefs – an ideology (Blili-Hamelin et al 2024, Torres 2023).

Artificial General Intelligence or AGI refers to the idea of machines reaching a human level of intelligence, a rather vague concept that still is missing a definition that is agreed-upon (Morris et al. 2023, Mitchell 2024, Blili-Hamelin 2024). Disagreements about AGI, AI and intelligence in general stem from their inherent connection to values. Diverse political, social, and ethical perspectives influence how we define both intelligence and AI, leading to a lack of consensus, as seen in debates over intelligence itself and AGI (Blili-Hamelin 2024 et al, Blili-Hamelin and Hancox-Li 2023).

3 Methodology

A case study research strategy (Eisenhardt, 1989, 1991; Yin, 2013; Dubois/Gadde, 2002) was used to abductively investigate TESCREAL and how it influences AGI. TESCREAL, operationalized as an ideology is influencing the public as well as institutional perception of artificial general intelligence (AGI), expectations regarding the potential capabilities and perils of the technology and subsequently the formulation of technology strategy and r&d budgets. A single case study design was chosen to investigate this phenomenon in a comprehensive way, utilizing secondary data like interviews, promotional material, articles and social media content. This kind of publicly available data seemed appropriate for the investigation, since

ideologies inherently aim to influence social behavior and create alignment using various forms of media, media that is intended to be shared and propagated.

4 Results

TESCREAL as an ideology and object of discourse is used to illustrate that the classification and interpretation of future scenarios are based on ideals, expectations and imaginations that aren't separate, unrelated factors but form a more or less cohesive but rigid system of beliefs – an ideology. The original concept of innovation as manifesting imagination introduced imagination a key factor in the preparation, diffusion and success of innovations. In this study we've enhanced the concept by integrating ideology, illustrating how it acts as a filter for what is deemed a preposterous, possible, plausible or probable future, framing, and highlighting futures as desirable or dystopian: Ideology not only defines what is desirable and what is not, as a complexity-reducing filter it also enables the argumentative reduction of future expectations by focusing on a specific narrative which is in this case TESCREALism as a "techno-utopian" vision of the future driven by "AI accelerationists" with the promise of producing radical abundance, reengineering humans, becoming immortal, colonizing the universe, creating an expanding interplanetary "post-human" civilization among the stars with trillions of people. The most straightforward way to realize this utopia, regarding to the TESCREAL ideology, is by pursuing the creation of super intelligent AGI (Artificial General Intelligence). They refuse the fear of AGI being able to surpass and potentially destroy humanity if something goes wrong, the dystopian version of their proposed future, and frame opposing positions and critics as alarmists, calling them "AI doomers". As an ideology, TESCREAL is offering a systems of belief that is reducing complexity and uncertainty by setting a certain future as possible and preferable and framing opposing ideologies (and their components) as negative, unrealistic or simply unattractive alternatives not worth considering.

5 Discussion & Conclusions

We propose that the preferable futures that key entities like imaginators recognize, factor in and push are not purely economic in nature, but driven by a rather rigid system of beliefs, based on and framed by a specific set of imaginations, ideals and expectations, an ideology. Now, we are integrating ideology and illustrating how it

acts as a filter: Ideology not only defines what is desirable and what is not, as a complexity-reducing filter it also enables the argumentative reduction of future expectations by focusing on a specific narrative which is in this case TESCREALism as shown above. We suggest further exploring the possibilities that imaginations of the future, such as science fiction, offer to value creation as well as sustainable and responsible decision-making. Moreover, we suggest considering the predictive potential of imagination-trends. Further considering the role of the imaginator in the process of imagination manifesting as innovation – e.g. imagination and social movements, imaginator as fraudster (e.g. Warren and Theranos). Finally, also the research community in innovation and technology management should foster a more design science-oriented paradigm in order to create which science fiction and future visions could inspire alternative social imaginations and imaginators. Future research should therefore also develop alternative technology visions and strategies since alternative desirable futures start with thinking about new possible alternative options. Without deconstructing the inherent flaws of current ideologies and future visions, strategies are doomed to follow a predefined script.

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The Impact of ESG Reporting on Corporate Reputation and Crisis Communication Strategies in the Age of AI

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In today's climate of heightened corporate accountability and demand for sustainable business practices, ESG reporting has become a critical determinant of corporate reputation. As transparency expectations rise, regulatory frameworks such as the European Sustainability Reporting Standards (ESRS) require businesses to monitor and report ESG metrics accurately. To meet these demands, AI plays a transformative role, enabling real-time data collection and analysis that allows companies to monitor their environmental impacts, social initiatives, and governance practices with precision. This paper examines how AI-driven ESG reporting influences corporate reputation and crisis communication practices. By automating data collection, ensuring compliance, and providing real-time insights, AI empowers companies to proactively address sustainability challenges while strengthening stakeholder trust. Using a systematic literature review, this study synthesizes existing research on corporate reputation and crisis communication within the context of ESG reporting. Overall, the findings suggest that using AI-driven ESG reporting in corporate communication offers significant benefits for reputation and stakeholder engagement, however, crisis management practices are not yet well-defined in this area. By positioning AI as a strategic enabler in the ESG domain, this paper contributes to the evolving discourse on sustainable corporate governance and responsible investment, offering practical insights for executives, sustainability officers, and corporate communicators.

Keywords:
ESG reporting, corporate reputation, crisis communication, strategies, stakeholder, artificial intelligence

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1 Introduction

In today's corporate landscape, building a strong reputation is inseparable from maintaining sustainable business practices and corporate accountability. As companies strive to meet these expectations, Environmental, Social, and Governance (ESG) reporting has gained momentum as a critical tool for demonstrating sustainability commitments while mitigating the risk of greenwashing accusations. The term "ESG" was first introduced in 2004 in the UN Global Compact report *Who Cares Wins*, developed in collaboration with major financial institutions to assess its integration into financial analysis (Monteiro et al., 2021). Over the past two decades, ESG reporting has transitioned from a voluntary practice to a regulatory requirement, though the timeline for this shift varies across regions. In the EU, mandatory ESG reporting applies to large companies starting in 2024, with small and medium-sized enterprises (SMEs) required to comply from 2026 (Gürlevük, 2024). These requirements, outlined under frameworks such as the European Sustainability Reporting Standards (ESRS), emphasize accuracy, transparency, and accountability in corporate sustainability disclosures. Beyond regulatory compliance, ESG reporting significantly influences corporate reputation. Investors, consumers, and other stakeholders increasingly rely on ESG metrics to assess corporate integrity and sustainability performance. Companies that demonstrate strong ESG commitments benefit from enhanced trust and credibility, whereas failure to comply or inadequate disclosures can result in reputational risks. Artificial Intelligence (AI) is revolutionising management practices and has a substantial impact on output and efficiency across a range of industries. AI technologies, such as machine learning and predictive analytics, are automating data processing, decision-making, and repetitive tasks (Garg et al., 2024; Pap et al., 2024). As AI becomes increasingly integrated into ESG reporting, it offers new opportunities to enhance the precision and reliability of sustainability data. AI-driven ESG reporting has the potential to automate data collection, ensure compliance, and provide real-time insights, enabling companies to proactively manage reputational risks and stakeholder engagement.

This paper examines the intersection of AI-driven ESG reporting, corporate reputation, and crisis communication. By conducting a systematic literature review, the study synthesizes existing research to explore how AI enhances ESG reporting, its impact on corporate reputation, and the challenges for crisis management. The

findings contribute to the evolving discourse on sustainable corporate governance, shedding light on the challenges of AI-driven ESG reputation and crisis management.

2 Theoretical Background

Corporate reputation is a critical intangible asset that influences stakeholder trust, customer loyalty, and investor confidence (Jucá et al., 2024). With the rise of sustainability concerns, Environmental, Social, and Governance (ESG) reporting has become a key mechanism for companies to demonstrate corporate responsibility and enhance their reputations. Prior studies suggest that companies with strong ESG performance tend to enjoy higher market valuation, improved stakeholder relations, and enhanced brand loyalty (Fatemi et al., 2018). AI-driven ESG reporting is a great way to enhance corporate transparency and credibility. By automating ESG data collection and analysis, AI can reduce human bias and improve the accuracy of sustainability disclosures (Wamba et al., 2021). However, concerns remain regarding the authenticity of ESG reporting, as firms may engage in selective disclosure or "greenwashing" to manipulate public perception (Krueger et al., 2021). This raises the question of how AI can be leveraged to ensure ESG reporting integrity and reinforce corporate reputation. Crisis communication is an essential component of corporate strategy, particularly in an era where social media and digital platforms can amplify reputational risks. Effective crisis management requires transparency, accountability, and swift response mechanisms, all of which ESG reporting can support (Almaqtari et al., 2021). However, our literature review reveals a significant research gap in how AI-driven ESG reporting intersects with crisis management.

3 Methodology

To shed light on this research topic, a systematic literature review was conducted to synthesize existing research on corporate reputation and crisis communication within the context of ESG reporting. This scientific method involved setting time-based limitations, focusing on the period between 2004 and 2025. In the research, we have utilized the Scopus scientific database, searching related keywords in different combinations. All versions of the search included the expression 'ESG' and then a related word in the context of crisis management, corporate reputation, AI, and communication. The database search combinations included ESG report as the

first keyword, followed by the terms: crisis, crisis management, reputation, corporate reputation, corporate image, AI, branding, and external communication.

Initially to find all related publications we have run an extensive search on Scopus with the following formula: ("ESG reporting" OR "ESG" OR "corporate sustainability") AND ("reputation" OR "crisis management") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "Environmental, Social, And Governance")). Upon running this search, we have found 764 publications altogether. In the search, we focused only on publications between 2004 and 2025 and those that have been published in English. Then we have narrowed down our search to specific key areas and ran the research with different combinations. First, we have added artificial intelligence and machine learning to the combination, and with that addition we generated results of 122 articles.

4 Results and Discussion

4.1 ESG Reporting and Corporate Reputation

The first area we have focused on was the connection between ESG reporting and corporate reputation. As the main focus of this paper is to examine how the implementation of ESG reporting can be leveraged in building a positive corporate reputation, this area deserves outstanding attention in the research process. To cover this topic four combinations were searched, including ESG and corporate reputation, branding, corporate image, and external communication. The below table presents the total number of publications found through these searches.

Table 1: Keyword search in Scopus database

ESG and Corporate Reputation	("Artificial Intelligence" OR "Machine Learning") AND ("ESG reporting" OR "ESG" OR "corporate sustainability") AND ("corporate reputation") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "corporate reputation")	41

ESG and branding	("Artificial Intelligence" OR "Machine Learning") AND ("ESG reporting" OR "ESG" OR "corporate sustainability") AND ("branding") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "branding"))	9
ESG and corporate image	("Artificial Intelligence" OR "Machine Learning") AND ("ESG reporting" OR "ESG" OR "corporate sustainability") AND ("corporate image" OR "image") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "image" OR "corporate image"))	66
ESG and external communication	("Artificial Intelligence" OR "Machine Learning") AND ("ESG reporting" OR "ESG" OR "corporate sustainability") AND ("external communication") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "external communication"))	0

Many times, corporate reputation was found mentioned in the context of investments or building an ESG investment portfolio. Corporate reputation and investors are tightly connected, as a strong corporate reputation can attract investors by signaling trustworthiness, stability, and long-term value, ultimately influencing investment decisions and stock performance. By including ESG data, investors can better understand why certain investments perform the way they do, improving their ability to predict returns (Pulian et al., 2025). Pikatza-Gorrotxategi et al. (2024) highlight that media coverage of companies shapes consumer perceptions, which in turn affect corporate reputation and financial performance. One way to enhance a company's reputation is through strong adherence to Environmental, Social, and Governance (ESG) investment criteria. As a company improves its ESG and sustainability reputation, it also strengthens its image as a reliable investment. Fatemi et al. (2018) support this by stating that company value increases when ESG performance is strong but declines when ESG-related concerns arise. Lee et al. (2016) further explore the positive relationship between a company's environmental responsibility and its financial performance, finding that greater commitment to environmental practices is positively correlated not only with financial success but also with improved operational efficiency and overall business performance. Daoud and Michalec (2022) further emphasize that consumers are more likely to purchase products and services from companies that demonstrate ethical behavior and

trustworthiness in the marketplace. As a result, businesses that earn consumer trust often become more attractive investment opportunities. Building trust among consumers and employees is a long-term process that requires years of commitment but ultimately yields significant benefits. However, trust issues are not limited to external markets; they also exist within organizations. When trust levels within a company are low, operational efficiency declines, slowing down processes. In contrast, a high level of trust accelerates workflows and enhances overall organizational performance. When it comes to branding, the research showed that literature on this topic is mainly concerned with greenwashing and green marketing. Paolo et al. (2025) investigate whether green investments and practices represent an authentic transformation in corporate strategy or a mere rebranding attempt. When searching "corporate image" we have encountered more articles on investment-related topics as well as with green marketing. More articles popped up looking into generative-AI assisted practices to evaluate ESG reports, but corporate image as part of branding was not highlighted.

4.2 ESG Reporting and Crisis Management

The second research area explored in this paper examines how the mandatory adoption of ESG reporting has compelled corporations to strengthen their crisis management practices. Crisis management is a broad and complex field, and within the realm of communication, it remains particularly sensitive. To get a comprehensive overview of how crisis management is affected by the mandatory ESG reporting, we have conducted searches with different keywords: crisis, crisis management, negative reputation, reactive communication. However, our search didn't get any results. The literature regarding crisis communication in relation with ESG reporting is none to very limited to this day. Neither was any literature when searched for negative reputation, and only two articles were found searching for reactive communication, and neither was covering our topic.

4.3 AI-Driven ESG Reporting

The following formula was implemented to research how artificial intelligence and machine learning facilitate ESG reporting: ("Artificial Intelligence" OR "AI" OR "Machine Learning") AND ("ESG report") AND PUBYEAR > 2003 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")) AND (

LIMIT-TO (EXACTKEYWORD , "ESG") OR LIMIT-TO (EXACTKEYWORD , "AI")). Altogether, 27 articles were found under this search. The majority of the results cover topics of enhanced efficiency and trust. Ensuring the reliability and transparency of ESG reporting remains a critical challenge, particularly as research on ESG assurance is still in its early stages (Nichole et al., 2024). Unlike traditional financial auditing, ESG assurance involves a diverse range of subjects and data types, making the verification process significantly more complex. To address these challenges, Nichole et al. (2024) propose leveraging artificial intelligence (AI) technologies and external data sources to enhance the accuracy and efficiency of ESG assurance. AI-driven systems can analyze large volumes of complex data, improving the verification process and strengthening the credibility of ESG disclosures. However, AI alone cannot guarantee ESG report integrity; third-party assurance organizations play a crucial role in ensuring compliance with recognized ESG standards (Liyan et al., 2024). The verification process, however, faces persistent challenges related to authenticity, credibility, and fairness (Garg et al., 2024). The selection of verifiers is particularly important as their expertise and impartiality directly impact the trustworthiness of the assurance process. To enhance ESG data verification, Liyan et al. (2024) introduce "Veri-Green," a blockchain-based incentive mechanism designed to improve the verifier selection process. Given the risks associated with verification systems—including reputational damage from approving inaccurate data and security concerns regarding sensitive corporate information—careful structuring and rigorous oversight are essential. Beyond assurance mechanisms, corporate sustainability reporting itself must be standardized and strategically aligned to ensure it serves as a genuine reflection of a company's sustainability trajectory (Gallego-Nicholls et al., 2025). Variability in report quality and emerging challenges highlight the need for continuous scrutiny, standardization, and commitment to best practices. As a vital communication tool, ESG reporting provides stakeholders with insights into an organization's sustainable practices, reinforcing corporate accountability and transparency.

5 Conclusion

Our systematic literature research in Scopus identified 116 relevant publications examining the connection between ESG reporting and corporate reputation, branding, corporate image, and external communication. Our major finding is that

corporate reputation is frequently discussed in the context of investment decision-making, with strong ESG performance often seen as a signal of stability, trustworthiness, and long-term value (Pulian et al., 2025). Scholars like Pikatza-Gorrotxategi et al. (2024) emphasize the role of media in shaping corporate reputation, while Fatemi et al. (2018) argue that positive ESG performance enhances company value, whereas ESG-related controversies can lead to reputational decline. Despite these insights, the literature review revealed a significant gap regarding the role of ESG reporting in corporate brand-building. Most of the existing research on branding and corporate image in ESG focuses on macroeconomic stability, green marketing and the risks of greenwashing (Kuzior et al., 2024; Szeberényi et al., 2024). This highlights the need for further research, also focusing on how AI can enhance brand positioning and reputation management while looking at its effect on brand trust through ESG reporting. Our review of ESG reporting in the context of crisis management yielded striking results. Despite the growing regulatory requirements for ESG disclosure, there is little to no existing literature addressing its impact on corporate crisis communication. This lack of literature suggests that while ESG reporting is widely acknowledged as a mechanism for transparency and stakeholder engagement, its potential role in crisis mitigation remains underexplored. Honest and proactive ESG communication could be a key tool in enhancing corporate trust and integrity, yet its strategic implementation in crisis scenarios remains an open question for future research.

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Limitations of the research should be acknowledged. This review was limited to publications indexed in Scopus and written in English, which may have excluded relevant studies published in other databases or languages. These limitations suggest that future research could benefit from a broader and more diverse data set to gain a more comprehensive understanding of the evolving relationship between AI-driven ESG reporting and corporate reputation.

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Energy-Intensive Industries - A Brief Overview of Milestones Supported by Diversity Index Data

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The production and consumption of energy is, in general, one of the main characteristics of technical development of a given economy. As the energy losses are defined as the ratio of energy produced and energy provided into the system, then it holds that the process of fewer transformations is the more efficient one. The mentioned physical law is valid for the process that is production, foremost in Energy-intensive industries (EII), e.g. construction, paper or chemical sector. The energy supply diversity index (based on the Herfindahl-Hirschman index principle) will be used to demonstrate the industry situation in countries in the European Union (EU). The comparison of milestones in changes of EII among EU countries allows us to observe that investment into sources and networks are governed by state regulation and natural facts (rivers, windy or sunny position of land) and not only by the market. Therefore, the mix of sources is imbalanced and has possible strategic and system risks for the future.

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1 Introduction

The energy strategy of any country or larger area or region plays a central role in the life of future generations. Decisions and activities that are made in the energy domain are long-term and overlap several generations. In the economy, there is an assumption of generation co-existence which is 21 years. Therefore, it is appropriate in this paper to use the thirty-year time frame to observe a change in the structure of sources in energy-intensive industries.

A coherent synthesis for energy consumption and efficiency for Shaanxi (205.000 square kilometres) province was published in PloS one (Yin, 2023). The author used, apart from other methods, the Shannon-Weiner (SWI) diversity index to calculate the diversity of the primary energy supply. While SWI is a logarithmic function, a similar index called Herfindahl-Hirschmann (HHI) is a quadratic function. The latter was used for the calculation of available data (Eurostat, 2024), most probably because it has an upper limit and allows comparison.

The Eurostat data are examined in line with criteria that are explained in section two of this paper, i.e., a literature review and following sections are devoted to methods. The main body of the paper is a presentation of the data analysis on energy-intensive industries (EII) in Europe. This way the paper makes a connection with the aforementioned paper, being aware that this analysis of EII is modest in comparison to the aforementioned paper. As Rubio-Varas and Muoz-Delgado (2019) stated, the energy intensity of China has declined. This could be a role model for the European Union (EU).

2 Theoretical Background / Literature Review

The importance of the diversity index in the context of energy is in the security of the country's inhabitants. Most of the demand (in general) is linked to the energy that has to be supplied. The greater the variety of sources or energy portfolio, the more secure the country is in respect of self-sufficiency. (De Rosa et al., 2022). The variation of source mix is not obvious if the observation is done on the scale of the EU as a whole standalone entity. Therefore, it makes sense to observe the diversity index from the regional point of view, and here the region is each European country. We may consider the question of how much the index converges within the EU

regions and, in this way, harmonizes the whole area. Specifically, the paper focuses only on energy-intensive industries, as these influence the consumption side of the energy balance.

The criteria for selection of industries were four pillars of modern society, i.e., cement, plastics, steel, and ammonia (Smil, 2025). Similar criteria are applied in the work of (Bähr et al., 2023). Thereupon we look at the construction industry/sector, paper pulp and printing industry, and chemical and petrochemical industry.

3 Methodology

The concept of diversity index comes from evolutionary and biological studies, where it is used to measure the structure of communities. In recent years, it has been introduced to measure the diverse structure of the energy sources used in a given area. Using data in energy balances, the index gives a value between 0 and 1. The lower the value, the better, because the variation of energy sources is greater. It is based on the Herfindahl-Hirschman index, which is a measure of competitive markets, and its value of 0.1 - 0.18 (Lopes Ferreira et al., 2011) is considered such one. Shares of items in the index are weighted by themselves. A certain issue of the index is that it is not a mathematical distance, therefore, the conclusions in comparing the results are difficult to make (Triguero-Ruiz et al., 2023). The authors suggest a new way to calculate the index, which will be discussed after the analysis.

The analysis has examined the HHI and additional sources of data from Eurostat, i.e., energy balances (EU Commission, DG Energy, Unit A4, 2024). From energy balances, the details specific to countries were searched so that the explanation of the milestones in the EII was possible.

4 Results

A general milestone for all countries was a transition from natural energy sources such as muscle, wood, and water to still natural but nonrenewable resources such as coal, oil, and gas (Gales et al., 2007). This transition was in each country related to the introduction of modern technologies. Although the excavation of coal and its burning was slightly overlapping the two eras. The coal age was in progress sooner in countries where taking advantage of peat was more common (the Netherlands,

for instance). Sweden is an example of use of thermal energy. By applying the technology of thermal energy storage, the country decreases its consumption (Sundarrajan et al., 2025). The pulp and paper industry is dependent on biofuels and electricity in Sweden.

Typical energy diversification started after the oil crisis in the 1970s, which could be considered another milestone that also influenced the industries development. The industry may grow more easily under the condition that the energy supply is uninterrupted and affordable.

Graph 1 illustrates the situation in EU countries.

- In 2022 was Malta heavily dependent on sources in the paper, pulp and printing industry, with the energy mix index reaching the value of 0.8016. The best energy mix was to achieve Hungary with 0.1951. Concerning the chemical and petrochemical industry, the best situation was in Bulgaria (0.1607) and the worst measure reached 0.6609 in Luxemburg. In the construction industry, three countries with similar diversity indexes are noticeable, i.e. 0.7951 and 0.7422 and 0.7005 for Croatia, Finland and Malta, respectively. The best situation was in Poland, 0.1703. Based on these results, we would conclude that most of the markets are concentrated. The closest to competitive markets are the following: Bulgaria, Hungary, and Poland (in alphabetical order).
- In 1992 the values for Malta were not at disposal, and so it is for Luxemburg in the pulp industry; this explains why it was substituted with zero value in the graph. The special case is Cyprus, which reached the value of 1 in all three industries. This country is dependent on oil supplies, which is supported by evidence (EU Commission, DG Energy, Unit A4, 2024). Sweden in the construction industry is also close to one, that is, 0.988. Greece is a similar region with 0.815 for the construction industry.

One can notice significant differences in thirty years of changes in adjusting the market of energy in energy-demanding sectors and industries. The largest increase in concentration was achieved in the construction sector in Denmark (difference of 0.26890). The minimum changes were again in the construction industry but in Sweden (difference of minus 0.6700).

The effect of inter-European energy exchange helps some countries increase the variation of their sources. This is not the case in Malta, as observed in the analysis. Our results are in line with De Rosa, Gainsford, Pallonetto, and Finn (2022), who claim that Malta has the greatest energy market concentration.

5 Discussion

The importance of the concentration index was proven in the study of EU countries in the period 1800 – 2010. The authors (Rubio-Varas & Muñoz-Delgado, 2019) showed the clusters of countries where firewood was dominant (Italy, Portugal, Sweden, and Spain) or coal dominant (Netherlands, Germany, United Kingdom and France). Each study has its limitations. The cluster analysis did not provide the observation of industries and their use of energy, as well as this study of industries did not provide the groups of countries that have a common strategy in energy use or a common feature.

Improvements in energy market analysis (be it factor analysis, descriptive statistics, or any other analytical tools) and development are possible. Suggested improvements are in the methods used to study diversity.

As the index anonymises the mix of energy sources, it is not possible to provide a better picture of the situation. The limitation can be overcome in other papers. This paper leaves the question open if there is a tool that allows us to avoid the problem of comparison by using another method instead, i.e. community dynamics metrics (codyn), where we only select the mean rank shifts. The diversity index, the number shows us the static situation. It is possible to capture the dynamics of the process of changes and substituting one source with another, such as coal energy power changed for solar. This means that a given area or country is introducing legal instruments that encourage the behaviour of inhabitants to use solar panels more frequently on the roof of their houses, despite the fact of somewhat higher initial costs and risks of taking care of all the types of equipment. Trying to look for the dynamics of this process, one can consider applying the codyn method and its function called rank shifts (Hallett et al., 2016).

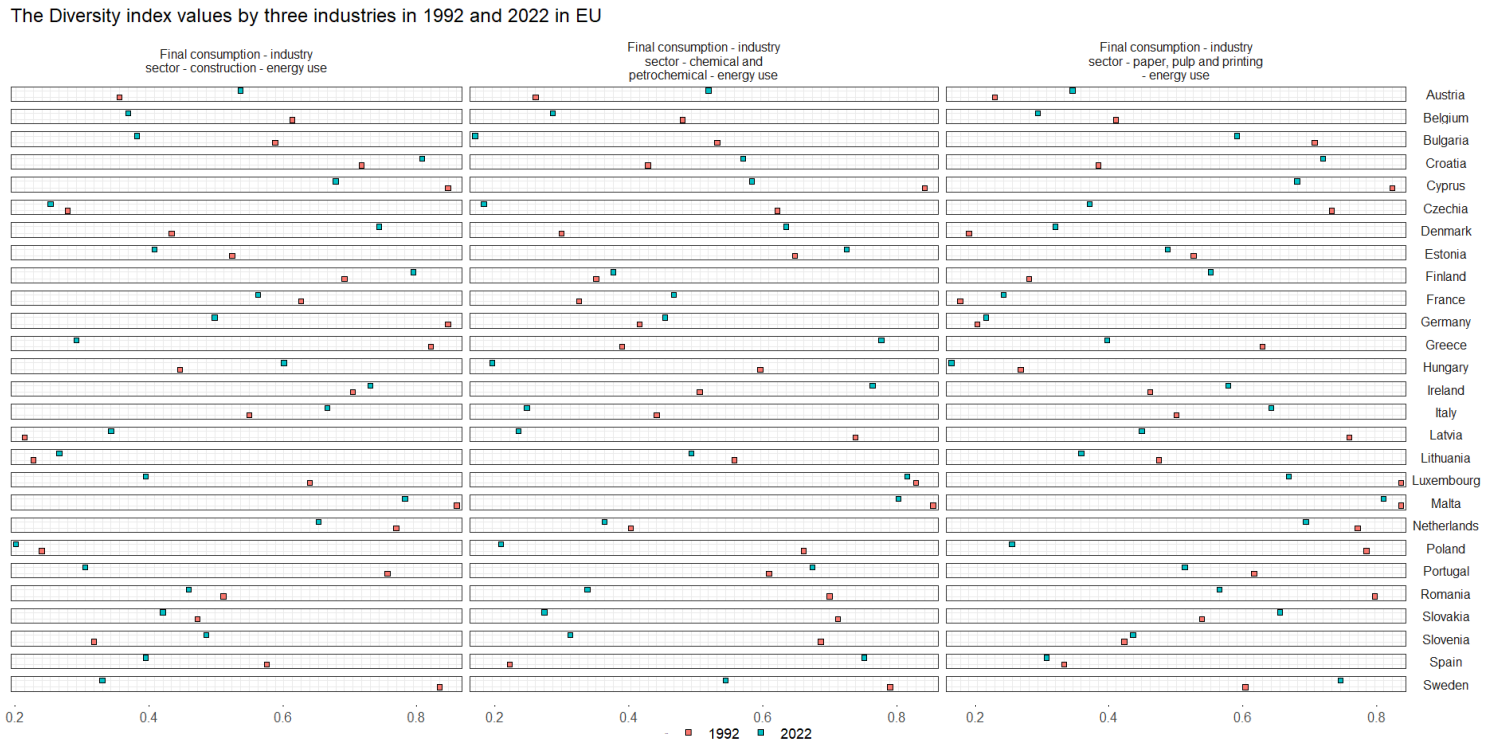

Figure 1: Comparison among industries and their use of energy

Source: Eurostat (2024), own processing

Note to Figure 1: Four observations were not available: Malta for the year 1992 all industries and Luxemburg in 1992 only for the paper, pulp, and printing industry. For obtaining the figure, the value zero was used.

6 Conclusions

The scarce resources that are employed in energy production are handled with a special focus on reducing carbon emissions. However, the political situation and pragmatic solutions to market imbalance or shortage make it difficult to shut off all coal power plants at once. The fastest phase-out of coal power is in Greece and the United Kingdom according to the World Institute of Resources (Jaeger, 2023). The Critical Raw Materials Act (European Critical Raw Materials Act - European Commission, 2023) emphasizes the diversification of suppliers of materials; however, cooperation on preventing climate change is based on overall contributors.

'The measurement of the power of all agents and consideration of the seven questions', writes Vojta (2025, p. 31) in his book on business strategy that is focused on Mister Sun tactics and strategies. In this measurement of power and in the questions, the idea of technical capacity as well as understanding the program, its acceptance, and most importantly belief is included. Concerning technical capacity and measurement, the paper and statistics presented have done humble but decent work. For the program itself, it can be considered as one piece of information to help better adjust the existing program. Regarding the belief, it might be assumed that we believe more easily in programs and strategies that are based on data, showing us what changes can happen in thirty years in industries that are quite complex in their technical processes.

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Do Masculine CEOs in High-ESG-Rated Companies Avoid Committing Fraud? Evidence From European Countries

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Globally, fraud cases and financial losses remain substantial across European countries. This research offers a novel perspective on the determinants of fraud by examining biological factors—specifically, masculine behavior influenced by the testosterone hormone. CEOs' masculine tendencies may drive riskier and potentially fraudulent behavior. Notably, masculine traits in males are often reflected in facial structure and can be objectively measured using the facial width-to-height ratio (fWHR). Conversely, robust internal controls and sound corporate governance are critical in preventing fraudulent activities. As global business practices evolve, sustainability has emerged as an urgent concern. In response, companies are increasingly adopting Environmental, Social, and Governance (ESG) principles to promote sustainable operations and mitigate fraud risks. This study investigates whether ESG practices moderate the relationship between CEO masculinity and the likelihood of financial statement fraud. The sample comprises high-ESG-rated firms from 2022 to 2024, as ranked by S&P Global, focusing on publicly listed companies on European stock exchanges. Data were analyzed using the STATA software, employing Fixed Effects Model regression. The results reveal that masculine CEOs in high-ESG-rated companies are less likely to engage in financial misreporting. This finding underscores the importance of balanced ESG implementation in reducing opportunities for misconduct.

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1 Introduction

Nowadays, fraud in the European region is a critical issue. Fraud cases and the median loss incurred in the European region remain high. In fact, globally, it has the highest median loss caused by fraud (Association of Certified Fraud Examiners, 2024). According to the *Report to the Nations* by ACFE (2024), fraud cases in the European region—including Western and Eastern Europe, as well as some countries from Western and Central Asia—accounted for 11% of cases and resulted in a median loss of $1,575,000, the highest among all regions. Furthermore, fraudulent financial statements were the most costly fraud schemes, alongside corruption and asset misappropriation schemes. The top-level management, including Chief Executive Officers (CEOs) and executives, were the primary perpetrators responsible for the highest number of cases and losses.

CEOs hold a superior position in making strategic decisions for the company, including disclosures in financial statements (Bouaziz et al., 2020). Interestingly, Wong et al. (2011) stated that a CEO's inherent traits play a crucial role in shaping behavior to make decisions. In line with the Upper Echelons Theory, CEOs' characteristics shape expectations and influence their decision-making (Hambrick & Mason, 1984). Masculine behavior drives males to be more aggressive and leads them to take risky decisions (Harymawan et al., 2023; Prasetyo et al., 2022). Furthermore, Kamiya et al. (2019) linked masculinity to a tendency to commit financial fraud, and Jia et al. (2014) then tied masculinity to social status, which drives males to manipulate accounting records solely to maintain their reputation as top performers. However, companies with strong quality control can limit the board's inclination to commit fraud and mitigate stock crash risk (Li et al., 2021). The growing emphasis on business sustainability has driven companies to adopt new business and management models that go beyond profit generation, incorporating Environmental, Social, and Governance (ESG) factors (Li et al., 2024).

This paper introduces a novel perspective to the literature on accounting behavior and fraud investigation by examining the relationship between individual biological factors and fraudulent activities. Additionally, it highlights the importance of integrating the ESG model into corporate management systems to inhibit fraudulent activities through comprehensive control measures, environmental protection, social inclusion, and good governance. The paper proceeds with theoretical reviews and

the rationale for hypotheses, followed by the methodology used to examine the influence of masculine behavior on fraudulent financial statements, with ESG practices serving as a moderating variable. Finally, the discussion covers the results and offers both practical and theoretical recommendations related to accounting fraud.

2 Theoretical Background / Literature Review

Masculine Behavior

Male masculine behavior is influenced by his testosterone hormone (Archer, 2006). High testosterone levels shape males' masculine traits, including aggression, dominance, and risk-taking behavior (Kamiya et al., 2019). Physically, testosterone influences male facial development by promoting the growth of cheekbones during adolescence, leading to a broader facial structure (Tjaraka et al., 2022; Verdonck, 1999).

Environmental, Social, and Governance (ESG)

ESG has become a significant global issue, as corporate performance in the fast-growing global economy and society is increasingly evaluated within the framework of Environmental, Social, and Governance (Li et al., 2021). For example, Henisz & McGlinch (2019) outlined the evaluation criteria for ESG: environmental aspects include energy consumption, carbon emissions, and other sustainability concerns; social criteria focus on maintaining and improving affected communities by addressing issues such as labor rights and poverty; and governance emphasizes the importance of sound corporate practices, including transparency and adherence to organizational codes of conduct.

Fraudulent Financial Statements

ACFE (2024) stated that fraudulent financial statements as the deliberate omission or misstatements of accounting data or critical information in the disclosed financial reports to manipulate the user perception, ultimately influencing their decisions about the company. There are various types of fraud within financial statement fraud

schemes, including fictitious or understated revenues, improper disclosure, improper asset valuations, overstated and concealed liabilities, etc.

Hypotheses Development

Masculine Behavior and Fraudulent Financial Statements

Males' masculine behavior is linked to a competitive attitude, aggression, strong determination, dominance, and a tendency for risk-taking (Kim et al., 2022; Tsujimura & Banissy, 2013). A higher level of masculine behavior in males is physically reflected in a wider facial shape or a higher fWHR (Verdonck, 1999). Stirrat and Perrett (2010) further added that a higher fWHR ratio has been correlated with a greater tendency to commit fraud. Zhang et al. (2023) and Harymawan et al. (2023) further reinforced these findings, stating that masculine-faced CEOs are willing to do whatever it takes—even manipulate accounting standards—to sustain their achievements. *H1: Masculine-faced CEOs are more likely to commit fraudulent financial statements.*

ESG and Fraudulent Financial Statements

Companies with strong ESG performance typically have more effective risk management and internal control systems (Li et al., 2024). They possess solid mechanisms to reduce fraudulent activities and enhance corporate compliance with relevant regulations and governance standards (Izzeldin et al., 2021). *H2: High-ESG-rated companies are more likely to avoid committing fraudulent financial statements.*

ESG and The Relationship between Masculine Behavior and Fraudulent Financial Statements.

CEOs with masculine faces are associated with risk-taking behavior and may even be more prone to commit fraudulent activities in order to achieve goals and maintain their social image (Jia et al., 2014; Kamiya et al., 2019; Kim et al., 2022). Conversely, companies with an ESG orientation are more transparent in their organizational management systems and decision-making processes, and they also comply with codes of conduct and regulations (Champagne et al., 2022). Accordingly, masculine CEOs of high-ESG-rated companies are restricted from manipulating financial

statements. *H3: Masculine-faced CEOs* in high-ESG-rated companies are more likely to avoid committing *fraudulent financial statements.*

3 Methodology

Research Data

The sample data in this research consist of companies with high ESG ratings from 2022 to 2024. S&P Global, a reputable sustainability expert institution, ranks the selected companies from a pool of over 7,690 global companies based on their ESG practices. Specifically, this research focuses on companies listed on stock exchanges in European countries. Companies in the financial sector, such as banks, are excluded due to differing financial regulations (Kim et al., 2022). Secondary data are sourced from companies' annual, sustainability, and financial reports, as well as from the Sustainability Yearbook released by S&P Global. All secondary data are obtained from companies' official websites, stock exchanges, and the S&P Global website. The sample selection follows a purposive sampling method to identify the most representative samples. The sample criteria include listing in the S&P Sustainability Yearbook, providing clear CEO images, containing data for Benish's M-score calculation, and including other financial data relevant to the control variables. Furthermore, the analysis technique employs Fixed Effect Panel Data Regression, and the data are processed using STATA version 17.0. The regression model is presented below.

$$Benish's\ M-score_{i,t} = \beta_0 + \beta_1 fWHR_{i,t} + \beta_2 ESGR_{i,t} + \beta_3 fWHR\ x\ ESGR_{i,t} + \beta_4 CEOAGE_{i,t} + \beta_5 ROA_{i,t} + \beta_6 LEV_{i,t} + \beta_7 FRIMSIZE_{i,t}$$

Operational Definitions and Measurement

Masculine Behavior

CEOs' masculine facial structure is measured using the facial width-to-height ratio *(fWHR)* (Kamiya et al., 2019; Kim et al., 2022). Harymawan et al., (2023) describe the fWHR calculation as the width (distance between the left and right cheekbones) divided by the height (distance from the midpoint between the inner ends of the

eyebrows to the upper lip). The *fWHR* is considered valid only for males (Jia et al., 2014); therefore, female CEOs were excluded from this research. Java-based image processing application ImageJ, along with an AI generator on the *fWHR* calculator website and Phyton package are used to ensure the highest measurement accuracy.

ESG

We use the ESG score released by S&P Global for each company that is included in their Sustainability Year Book. Specifically, only companies listed on the stock exchange in Europe. Companies in the top 1% are assigned a value of 3, while those in the top 5% and top 10% are assigned values of 2 and 1, respectively.

Fraudulent Financial Statements

The Bensih M-Score model is used to indicate fraudulent financial statements (Valaskova & Fedorko, 2021). A company will be classified as engaging in financial manipulation if its M-Score is greater than or less negative than -2.2. Below is the equation of Beneish M-Score.

M-score= -4.84 + 0.92 DSRI + 0.528 GMI + 0.404 AQI + 0.892 SGI + 0.115 DEPI – 0.172
SGAI + 4.679 TATA – 0.327 LVGI

Control Variables

Additionally, the control variables in this research include the CEO's age (CEOAGE), which represents their age in the observation year. Return on Assets (ROA) and Leverage (LEV) ratios are also considered to assess companies' financial performance. ROA is calculated by dividing Net Income by Total Assets, while LEV is determined by dividing Total Debt by Total Equity. Lastly, Firm Size (FIRMSIZE) is measured as the natural logarithm of Total Assets.

4 Results

Descriptive Statistics Analysis

The study population consists of 63 companies listed on stock exchanges in European countries from 2022 to 2024, based on the Sustainability Yearbook released by S&P Global. Based on the summary of observational data, the average **Benish M-score** is **-2.624,** approaching **-2.22**, which indicates a potential risk of fraudulent financial statements. Subsequently, the average **CEO's face ratio** is **1.75**, with a median **fWHR** value also at **1.75**. Nearly half of the CEOs (**49%**) have a face ratio above the median and average value. Moreover, most CEOs are **58 years old**, with the oldest being **76 years** and the youngest **42 years**.

Panel Data Regression

The **Fixed Effect model** is the most appropriate for estimating panel data of this study.

Table 1: Fixed Effect Model Regression

Benish M-score (Y)	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
fWHR (X)	3.839	1.763	2.18	.032	.342	7.336	**
ESG (M)	2.795	1.341	2.08	.04	.134	5.456	**
fWHR*ESG	-1.556	.762	-2.04	.044	-3.067	-.044	**
CEO_AGE	-.004	.016	-0.25	.802	-.037	.029	
ROA	.078	.03	2.63	.01	.019	.137	**
LEV	.094	.084	1.13	.263	-.072	.261	
F_SIZE	.146	.134	1.08	.282	-.121	.412	
Constant	-11.192	3.532	-3.17	.002	-18.198	-4.186	***
R-squared		0.120	Number of obs			170	
F-test		1.970	Prob > F			0.001	
*** p<.01, ** p<.05, * p<.1							

Source: STATA results, 2025.

Based on the results, the **fWHR variable significantly influences the Benish M-score**, with a p-value of **0.032**. The **ESG variable** also has a significant influence on the Benish M-score at the **95% confidence level**, with a p-value of **0.04**. Furthermore, the **moderating variable**—the interaction between **fWHR and ESG**—has a p-value of **0.044**, which is below the 0.05 significance level. Among the

control variables, **ROA** shows a significant influence on the Benish M-score (p-value = **0.01**). However, the other control variables do **not** significantly influence the dependent variable (**Y**).

General Least Square (GLS) Regression

To ensure that the Fixed Effects model is robust and free from heteroscedasticity and autocorrelation, GLS is employed. The results of the GLS regression still show that fWHR, ESG, and fWHR**ESG significantly influence the Benish M-score, even at the higher significance level of 0.01. Specifically, fWHR, ESG, and fWHR*ESG have p-values of 0.005, 0.007, and 0.008, respectively. Furthermore, there is no multicollinearity in the data, as the correlation between the independent variables is below 0.75.

5 Discussion

Masculine Behavior and Fraudulent Financial Statements

The results indicate that masculine behavior, as proxied by the facial width-to-height ratio (fWHR), significantly influences the indication of fraudulent financial statements. Empirical evidence suggests that biological factors shaping human behavior—such as masculinity in males—are associated with heightened aggression, dominance, and an increased propensity for risk-taking (Kim et al., 2022; Tjaraka et al., 2022). The positive coefficient obtained in the analysis reveals a direct relationship, indicating that a higher fWHR is associated with a greater likelihood of financial statement fraud. Consequently, this study concludes that CEOs with more masculine facial features are more likely to engage in financial misreporting—such as manipulating accounting records or breaching accounting standards—to sustain superior performance and achieve higher profitability (Harymawan et al., 2023; Wong et al., 2011).

ESG and Fraudulent Financial Statements

This study demonstrates the significant influence of ESG on financial statement fraud, suggesting that a company's ESG management model is associated with the likelihood of fraudulent financial reporting. Interestingly, the direction of this relationship, as indicated by the positive coefficient value, suggests that even

companies implementing ESG initiatives may still engage in financial statement fraud. In this study, the ESG score is calculated as the average of total scores across three dimensions: Environmental, Social, and Governance (including economic factors). At times, a company may achieve a high overall ESG score, while one component—typically Governance and Economic—remains low, offset by higher scores in the Environmental and Social categories. For example, many firms prioritize environmental and social initiatives to enhance public image, often at the expense of internal governance and financial oversight. Such imbalances can increase the risk of executives manipulating accounting records, either to portray profitability or to survive periods of financial distress (Kim et al., 2022). Moreover, according to the ACFE's 2024 report, other forms of fraud—such as asset misappropriation and corruption—remain prevalent and occur more frequently than financial statement fraud.

ESG and The Relationship between Masculine Behavior and Fraudulent Financial Statements.

Support for Hypothesis 3 is evident in the findings of this study. The results suggest that ESG performance can attenuate the positive relation between masculine behavioral traits—proxied by fWHR—and financial statement fraud. In particular, CEOs exhibiting masculine facial characteristics are generally more prone to engage in fraudulent behavior. However, when operating within firms that demonstrate strong ESG performance and implement comprehensive internal control systems, this tendency is substantially reduced (Li et al., 2024).

6 Conclusions

This study introduces a novel determinant in the theory of accounting fraud by investigating the influence of biological factors on human behavior. Specifically, it explores the relationship between CEOs' masculine facial features and the likelihood of issuing fraudulent financial statements, with ESG practices serving as a moderating variable. The findings suggest that CEOs exhibiting more masculine facial characteristics are statistically more prone to engaging in financial statement fraud. However, this tendency can be significantly reduced when companies rigorously implement ESG frameworks within their governance structures. Moreover, the study emphasizes the importance of integrating all three ESG dimensions—Environmental, Social, and Governance—along with economic

considerations, treating them as equally vital components of a sustainable corporate strategy. This research is limited to companies listed on European stock exchanges that have high ESG ratings. Therefore, future studies could expand the scope by including companies from different regions with varying ESG ratings, and by incorporating additional variables—such as market reactions—to further enrich the analysis.

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The Role of Social Media in the Implementation of Sustainable Marketing: Consumer Behavior, Brand Engagement, and Green Consumption

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Many companies integrate sustainable business practices into their marketing strategies, enhancing supply chain management, product development, and decision-making. The growing use of social media has facilitated green advertising, enabling knowledge exchange and awareness. This study examines the impact of social media on sustainable marketing, focusing on consumer behavior, brand engagement, and green consumption. It aims to determine how digital technologies, social media actors, and interactions support sustainable marketing within companies. A literature review of Scopus and Web of Science databases identifies key trends and empirical findings in the researched field. Results highlight that social media promotes eco-friendly products, raises environmental awareness, and fosters engagement through influencer marketing. Findings suggest that sustainable brand positioning via social media enhances consumer trust and loyalty, while digital marketing interactions significantly influence green purchasing decisions. Additionally, the accessibility and interactivity of social media content shape consumer attitudes toward sustainable brands. Study limitations include the exclusive use of two databases and a restricted publication timeframe. Practical implications suggest that companies should strategically leverage social media to educate and engage consumers in sustainability. This research contributes to sustainable marketing by illustrating how digital technologies drive environmental, social, and economic responsibility while fostering consumer participation.

Keywords:
social media,
sustainable marketing,
consumer behaviour,
brand engagement,
green consumption,
digital marketing,
digital technologies

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1 Introduction

Sustainability has become a crucial global priority, driven by the urgent need to address environmental degradation, resource depletion, and climate change (Vilkaite-Vaitone, 2024). Governments, companies, and consumers are increasingly recognizing the importance of adopting sustainable practices to reduce the negative impact of economic activities on the planet (Adwan & Altrjman, 2024). As societies transition towards greener economies, companies are expected to integrate sustainability into their operations, ensuring long-term environmental, social, and economic responsibility (Yadav et al., 2018). This shift is not only necessary for regulatory compliance but also for maintaining competitiveness in markets where consumers are becoming more environmentally conscious. Within this context, marketing plays a pivotal role in promoting sustainable behaviors and fostering consumer engagement with green products and services. Sustainable marketing goes beyond traditional promotional strategies by integrating ecological and ethical considerations into branding, communication, and consumer relations (Oka & Subadra, 2024). Social media, as a powerful digital tool, has transformed how companies engage with consumers, providing an interactive platform to educate, influence, and encourage sustainable consumption (Bryła et al., 2022). Given the increasing reliance on digital communication, it is essential to explore the role of social media in implementing sustainable marketing strategies, shaping consumer behavior, and strengthening brand engagement in the sustainability-driven marketplace.

This study aims to determine how digital technologies, social media actors, and interactions contribute to sustainable marketing within companies, emphasizing the role of social media in its implementation. This paper is structured as follows: following the introduction, the research methodology is described, followed by the presentation of the main research findings. The author's interpretation of the results and the key conclusions are systematically summarized in the final chapter.

2 Methodology

The literature search was conducted on February 2nd, 2025, across two databases: Scopus and Web of Science (WoS). To ensure a comprehensive yet focused search, the following search query was applied: *("sustainable marketing" AND "social media")*

within TITLE-ABS-KEY fields in Scopus and the TOPIC field in WoS database. The initial search retrieved 44 results from Scopus and 31 from WoS. To capture the most recent trends, findings, and discussions in the field, only papers published in 2024 and 2023 were taken into consideration, which resulted in 23 papers from Scopus and 8 from the WoS database. The selected papers were analyzed to identify key topics, trends, and empirical findings related to the impact of social media on sustainable marketing. The review process consisted of three main stages: i) *content screening*: where titles, abstracts, and keywords were reviewed for relevance; ii) *full-text evaluation*: in which articles that met the inclusion criteria were thoroughly examined to extract relevant findings; iii) *synthesis and thematic categorization*: where the extracted data was systematically categorized and linked to the research question and study objectives. Following the review process, 17 papers that fully aligned with the topic were included, while others were excluded from the analysis due to irrelevance, duplication in the databases, or unavailability.

3 Results

The research objective and research question served as a foundation for guiding the authors toward relevant findings. Since the main aim of this scientific paper is to examine the role of social media in the implementation of sustainable marketing, six key themes were identified from analyzed secondary data. These themes, explored by various researchers, include corporate social responsibility, green consumption, consumer behavior, sustainable marketing, brand engagement, and influencer marketing (Table 1).

Corporate social responsibility (CSR) practices, particularly environmental and social CSR, have a significant impact on consumer purchasing intentions (Chan et al., 2024). The findings of Adwan & Altrjman (2024) suggest that marketing managers play a crucial role in aligning overall business strategies with sustainability initiatives, ensuring that CSR efforts build consumer trust and provide a competitive advantage. Similarly, Khan et al. (2024) highlight the strong connection between sustainability, product innovation, and responsible marketing, emphasizing the growing importance of CSR and stakeholder engagement.

Green consumption is highlighted in the study of Armutcu et al. (2024). In their study authors emphasize the strong impact of social media and digital marketing on green food purchasing behavior. Similarly, the role of social media in promoting sustainable consumption is also noted by Vilkaite-Vaitone (2024) and Chan et al. (2024). The authors highlighted social media's role as a key communication channel for sustainability efforts. Oka & Subadra (2024) suggest that digital tools enhance cultural preservation, environmental sustainability, and economic benefits, particularly in eco-tourism. Sustainable advertisements and user-generated content also play a crucial role in green consumption (Caratù et al., 2024). Studies by Adwan & Altrjman (2024), Parra et al. (2024) and Wang & Li (2024) highlight the significant impact of green advertising, with higher online engagement linked to sustainability-related content (Dash et al., 2023). Chan & Imad (2024) explore how social media influences consumer decisions to revisit green resorts, showing that content sharing and accessibility enhance a destination's green image and consumer behavior. Arora et al. (2023) emphasize the role of companies in labeling eco-friendly products and noting that social media, with its extensive reach, effectively promotes sustainable products and addresses environmental challenges through green consumerism.

Consumer behavior is the most frequently discussed topic in the analyzed scientific papers. Social media platforms play a crucial role in raising consumer awareness (Armutcu et al., 2024; Chan & Imad, 2024), facilitating information exchange, influencing purchasing decisions (Vilkaite-Vaitone, 2024), driving engagement (Khan et al., 2024; Mohammad et al., 2024; Wangsa & Sin, 2024), fostering commitment (Khalid et al., 2024) and promoting sustainable consumption (Chan et al., 2024; Wang & Li, 2024). Additionally, social media enhances visibility and engages consumers in the purchasing process (Oka & Subadra, 2024). Caratù et al. (2024) highlight that Millennials and Generation Z engage more with eco-fashion brands, with sustainable ads capturing their attention earlier and for longer, ultimately leading to purchases. Adwan & Altrjman (2024) emphasize the impact of brand perception on consumer behavior. Dash et al. (2023) show that social media influences and encourages action on environmental issues. Arora et al. (2023) emphasize that social networks effectively promote sustainable products and address environmental challenges through green consumerism.

Armutcu et al. (2024) illustrated the role of *sustainable and digital marketing strategies* in green promotions, a concept also underscored by Caratù et al. (2024) and Chan & Imad (2024). Adwan & Altrjman (2024) emphasized the development of sustainability plans as a tool for communication and decision-making, while Chan et al. (2024) and Khan et al. (2024) explored the role of user-generated content and ethical business practices. The promotion of digital growth is highlighted in the studies of Lin et al. (2023) and Walhidayat et al. (2024), while Dash et al. (2023) and Parra et al. (2024) focus on encouraging responsible consumption. Oka & Subadra (2024) warn that social media platforms serve as powerful branding and promotional tools, helping to increase visibility, engage tourists, and strengthen sustainable tourism strategies.

Khalid et al. (2024) emphasize the critical role of *brand engagement* and sustainability marketing in strengthening the green brand image (Chan & Imad, 2024; Wang & Li, 2024; Wangsa & Sin, 2024), driving consumer engagement (Mohammad et al., 2024), fostering brand loyalty (Caratù et al., 2024; Khan et al., 2024; Oka & Subadra, 2024), and enhancing consumer commitment. Findings by Chan et al. (2024) suggest that consumers prefer brands demonstrating ecological responsibility and ethical business practices, which influence their trust and emotional connection to the brand. The study by Adwan & Altrjman (2024) highlights the significant impact of brand perception on green advertising and consumer purchase behavior, showing that higher online engagement with sustainability-related content leads to stronger brand loyalty. Lin et al. (2023) highlight that integrating brand equity into a company's strategic concept is crucial for achieving competitive and sustainable brand development.

Influencer marketing plays a crucial role in targeting consumers (Armutcu et al., 2024). By leveraging their credibility and broad audience reach, influencers shape consumer behavior and promote sustainable consumption (Vilkaite-Vaitone, 2024). Findings indicate that influencer marketing positively impacts the cognitive, affective, and conative aspects of sustainable purchasing decisions, reinforcing the idea that authenticity and trust in influencers enhance their effectiveness. Additionally, influencer endorsements (Caratù et al., 2024) are important in promoting green consumption. Furthermore, collaboration between marketing experts and influencers improves communication with the target audience on social media platforms (Dash et al., 2023).

Table 1: Research findings

	Findings					
Authors	*Corporate social responsibility*	*Green consumption*	*Consumer behavior*	*Sustainable marketing*	*Brand engagement*	*Influencer marketing*
(Armutcu et al., 2024)		X	X	X		X
(Vilkaite-Vaitone, 2024)		X	X			X
(Khalid et al., 2024)			X		X	
(Chan et al., 2024)	X	X	X	X	X	
(Oka & Subadra, 2024)		X	X	X	X	
(Caratù et al., 2024)		X	X	X	X	X
(Adwan & Altrjman, 2024)	X	X	X	X	X	
(Mohammad et al., 2024)			X		X	
(Chan & Imad, 2024)		X	X	X	X	
(Khan et al., 2024)	X		X	X	X	
(Walhidayat et al., 2024)				X		
(Parra et al., 2024)		X		X		
(Wang & Li, 2024)		X	X		X	
(Wangsa & Sin, 2024)			X		X	
(Dash et al., 2023)		X	X	X		X
(Arora et al., 2023)		X	X			
(Lin et al., 2023)				X	X	
SUM	*3*	*11*	*14*	*11*	*11*	*4*

Source: Author's work

4 Discussion and conclusion

Consumer behavior emerges as the most prominent theme covered in the defined search query, appearing as a key concept in a total of 14 scientific papers (82%). Following this, *green consumption, sustainable marketing*, and *brand engagement* rank second, each featured in a total of 11 scientific papers (65%). Themes related to *influencer marketing* (4 scientific papers, 24%) and *corporate social responsibility* (3 scientific papers, 18%) hold the third and fourth positions. The findings highlight that promoting consumer awareness and engagement is key to advancing corporate social responsibility (CSR) practices. Social media plays a crucial role in implementing

sustainable and digital marketing strategies, boosting business visibility, fostering green consumption, and strengthening brand loyalty. Additionally, influencer marketing is particularly effective for targeting consumers, while social media's impact on sustainable marketing is most evident in shaping consumer behavior.

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Tourism and Sustainability: Exploring the Role of AI-Driven Tourism Practices in Shaping Consumer Sustainable Behaviour

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The actors of the tourism industry worldwide keep implementing more digital solutions into the tourism services, including artificial intelligence (AI) tools to improve travel planning, pricing, marketing and other business functions, and to increase the quality of tourism experience. Sustainability, on the other hand, is of significant importance in order to maintain economic efficiency, social equity and ecological consideration. However, various gaps and inconsistencies between providing and using AI and sustainable tourism services are noticed. Thus, this paper aims to analyse the scope of cohesion between AI application and sustainability practices in the sector. The exploratory empirical research revealed that AI still plays a limited role in shaping the sustainable behaviour of the consumers of tourism services.

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1 Introduction

Among technological advancements, artificial intelligence (AI) becomes a force, which provides new opportunities and operational efficiencies in the tourism sector, including increasing sustainability and shaping sustainable behaviour of the consumers of tourism services (Siddik, Forid, Yong, Du & Goodell, 2025). However, the scientists acknowledge that the development of sustainable tourism itself is not quite clear. Accordingly, it is not simple to define, how particular technologies could have an impact towards sustainable tourism (Majid, Tussyadiah, Kim & Pal, 2023). On the other hand, AI is also a complex phenomenon, still in its experimental stage (Florido-Benítez & del Alcázar Martínez, 2024), thus the consumers of tourism services may also have various experience levels and expectations regarding AI. One should state that scientific literature gives much attention to the presentation of AI significance regarding sustainability practices (for example, Ionescu & Sârbu, 2024; Shuai & Karia, 2024). However, there is a scarcity of scientific research on the relationship of AI, tourism services and sustainable behaviour starting at industrial level and ending at individual (consumer) level. Even more, the research to analyse and compare the contexts with socio-economic and cultural differences regarding AI-driven tourism practices and consumer sustainable behaviour would be of a great significance.

Thus, ***the scientific research problem*** could be formulated as follows – what is the role of AI-driven tourism practices in shaping consumer sustainable behaviour?

The aim of the paper is to define how AI-driven tourism practices shape consumer sustainable behaviour.

In the theoretical part of the paper, the main concepts of sustainability and AI are explained, the scope of application of AI in tourism regarding sustainability is revealed and the main challenges regarding consumer behaviour in adapting AI approaches, which could lead to sustainable tourism practices, are presented. ***In the methodological part***, research methods are presented. In the ***Result and discussion parts*** the main trends regarding consumer behaviour in connection to sustainability and AI are defined.

Research methods: scientific literature analysis, case analysis, semi-structured interviews and thematic analysis.

2 Theoretical Background / Literature Review

Sustainable tourism balances between the three fundamental pillars of sustainability – environmental, social and economic (Butler, 1999) in meeting human needs while also tending to ecological needs (Rastegar, Higgins-Desbiolles & Ruhanen, 2023). Based on the framework introduced by UNEP and WTO (2005), the aims for the sustainable tourism include economic viability, local prosperity, employment quality, social equity, visitor fulfilment, local control, community wellbeing, cultural richness, physical integrity, biological diversity, resource efficiency and environmental purity.

Sustainable consumers of tourism services could be characterised by behaviour, which is environmentally sustainable, i.e., such individuals don't have an adverse effect on natural environment and responsibly engage in sustainable tourism practices, while prioritizing environmental protection and sensitivity (Saltik & Akova, 2024).

AI-driven tourism practices can be defined as the integration of technology and tourism, where autonomous systems without a human control are utilized to enhance and streamline travel experiences, by offering efficient and convenient solutions for travellers (Shuai & Karia, 2024). The authors define the following expressions of AI in tourism: visitor-facing online services and offline service equipment and facilities; AI tour guide service; chatbots and voice assistants; language translation applications; Map Apps; facial recognition; robots and smart travel assistants; VR/AR/MR (headsets); forecasting systems (Ionescu & Sârbu, 2024; Shuai & Karia, 2024).

The implementation of these technologies makes an impact at *industrial*, *business* and *consumer* levels. *At industrial level*, AI is capable of replicating human intelligence and developing mechanical, analytical, intuitive, and empathic intelligence (Shuai & Karia, 2024). Tourism enterprises use biometric, emotional data of tourists by employing AI for generating trends in consumption, income, business opportunities and threads (Doborjeh, Nigel, Doborjeh & Kasabov, 2022) in order to meet unique

consumer needs and increase consumer loyalty and satisfaction (Shuai & Karia, 2024). At *consumer level*, AI can predict and understand tourists' preferences, thus enhancing their overall satisfaction through customized services.

One should state that AI usage to support sustainability initiatives may have a significant impact *at societal level* as well through the optimization of the allocation of resources, improving the management of waste, contributing to energy consumption, reducing the industry's ecological footprint, improving health measures, generating corporate social responsibility, decreasing the destruction of cultural heritage sites (Elkhwesky, El Manzani & Salem, 2024; Lv, Shi & Gursoy, 2021).

However, Patrichi (2024) emphasises the need for the improvement of AI adaptation in sustainability practices, especially data quality and availability, algorithmic transparency and interpretability, enhancing trust and accountability in the decision-making process. One should state that because AI includes various data and sensitive information, it is difficult to provide the necessary security from cyberattacks and other violations of privacy (Florido-Benítez & del Alcázar Martínez, 2024). According to Kelly & Lawlor (2021), the tourists may be reluctant to share their private data and use smart technologies because of particular perception, attitudes and experience regarding AI. Finally, the attitudes and experience regarding sustainable practices is also uneven among the consumers of tourism services (Holmes, Dodds & Frochot, 2021).

Thus, in the next parts of this paper the research methodology and empirical research results will be presented in order to analyse the aspects of AI-drive tourism services and sustainable behaviour.

3 Methodology

The aim of the empirical research was to define the main trends regarding AI-driven tourism practices to choose sustainable behaviour in India and Lithuania. Those countries were chosen because of their differences in socio-economic and technological development, and cultural differences (Western vs. Eastern approach). **The research objectives** were as follows: 1) to reveal the availability of AI in tourism services from the perspective of research participants; 2) to find out the

attitudes of research participants regarding sustainability in tourism; 3) to analyse the willingness of research participants to use AI to possess a sustainable behaviour.

Semi-structured interview's method was chosen in order to reveal current realia regarding AI and sustainable behaviour without asking the respondents to choose predefined statements. Based on the research objectives, the following questions were prepared: 1) How do you notice AI while using various tourism services (including accommodation, dining, shopping, transportation, excursions, other activities)? 2) Do you purposefully use some AI tools while ordering and (or) using tourism services? Why? Why not? 3) How important is it for you to use sustainable tourism services? Why? 4) Do you use AI tools to order/use sustainable tourism services? If not, would you wish to use them? In which areas? 5) What do you think, how do AI tools help you to promote sustainable tourism services? Please provide some examples.

The research was *exploratory* in nature, mainly concentrating on the representatives of late Generation Y (born 1990-1996) and early Generation Z (born 1997-2000), scientifically seen as individuals, depending on intense technology adaptation and significantly positive attitudes towards sustainability (Çalışkan, 2021). The respondents were chosen as particular cases. They are working in the tourism sector or teaching tourism subjects (teachers) or studying tourism topics (thus, having particular understanding regarding sustainability and application of smart technologies in the tourism area). Additionally, some of them are enthusiastic travellers, which are in need to get particular tourism services, and (or) individuals, who are using various AI technologies in their work and personal life. Six respondents from India and six respondents from Lithuania with above stated characteristics were chosen for the interviews. Respondents were informed about the anonymity of the empirical research data and the possibility to withdraw from the research at any time. Every respondent was coded, noting them as Respondent A, Respondent B, etc., adding LT (Lithuanian) or IN (Indian). The interviews took place online. 6 Indian respondents and 5 Lithuanian respondents participated in the research. The answers were transcribed. Thematic analysis for the content of the answers was used.

4 Results

AI in tourism services. The respondents both from India and Lithuania recognise AI in various apps (for example, travel apps), restaurant /dining search algorithms, websites of tourism services (including advertisements) and especially chat boxes, when they give the questions and are provided with answers (Respondent A_LT, Respondent E_IN, Respondent G_IN). However, some respondents emphasised that there is "not enough AI in the tourism sector" (Respondent H_IN).

The willingness of the respondents to use AI in tourism services. Mostly, the respondents are using AI while searching more information for a particular place (Respondent A_LT), planning the route (Respondent A_LT, Respondent F_LT, Respondent E_IN, Respondent G_IN), dining services (Respondent D_IN, Respondent E_IN), accommodation (Respondent E_IN, Respondent F_LT). As Respondent E_IN, while providing various examples of AI application, noted: "AI makes everything smoother and more personalized".

However, some respondents don't use AI at all (on purpose, as in the case of Respondent B_LT, or simply because not seeing adequate options, as in the case of Respondent C_LT, Respondent H_IN, Respondent I_IN).

The significance of sustainability. The respondents in general emphasised the importance of sustainability while applying waste/garbage management (Respondent B_LT, Respondent C_LT, Respondent E_IN), buying reusable products / less plastic (Respondent C_LT, Respondent_E), driving an electric car (Respondent C_LT), supporting local communities (Respondent_E_IN), using eco-friendly services (Respondent E_IN).

The respondents also emphasised the importance of sustainable practices as a tool to preserve this world for future generations / for the next generation travellers (Respondent D_IN, Respondent E_IN, Respondent G_IN, Respondent I_IN), to decrease negative impact to the environment / make the environment clean (Respondent_E_IN, Respondent F_LT). Respondent J_LT, noted that they "prefer tourism services which provide and encourage sustainable practices". However, there was one respondent, who "is not concerned about sustainability" (Respondent

A_LT), but it shouldn't be evaluated negatively because this respondent simply is not convinced about the portrayal of sustainable services as such.

AI in shaping sustainable behaviour. The research results revealed that the AI application regarding sustainability in the tourism sector looks limited. The respondents even revealed the concerns that "not everything that looks sustainable, is really sustainable" (for example, Respondent A_LT and Respondent B_LT). The most of respondents didn't use AI specifically for sustainable tourism, even if they wished to (for example, Respondent C_LT, Respondent D_IN, Respondent E_IN, Respondent F_IN, Respondent H_IN, Respondent I_IN, Respondent K_IN). Respondent G_IN, for example, tried using it but "didn't succeed that much". Two respondents mentioned that they used AI in the case of sustainable accommodation but only in a limited way (Respondent I_IN, Respondent J_IN).

5 Discussion

Empirical research revealed that despite a variety of the options of AI application areas, the respondents both from India and Lithuania mostly revealed very few and quite simplified examples of AI application, including chatbots, virtual assistants, some travelling or restaurant searching algorithms. Accordingly, the practical usage of AI in the tourism sector looked also somehow simplified with some exceptions, taking into account that some respondents even don't see any purpose to use AI. One should mention that hospitality education of respondents highly increases the knowledge and ability to notice AI and sustainability opportunities (Respondent E_IN, Respondent F_LT).

In general, both Lithuanian and Indian respondents emphasise the importance of sustainability, however, some differences in the approach regarding sustainability based on different cultures were noticed. Lithuanian respondents emphasised the importance of sustainability in a *current* world (for example: "I contribute to a more sustainable world (*now*)" – Respondent B_LT), while Indian respondents emphasise future generations (as Respondent D_IN noted, "it is extremely important to keep the nature as it is or better for the coming generations"). These answers of Indian respondents reflect the deeply rooted sense of sustainability and community approach.

Most of the respondents confirmed that they didn't use AI regarding sustainable tourism services, or tried to use but not very successfully. However, the respondents have a lot of ideas how to apply AI in shaping sustainable behaviour (planning sustainable trips, accommodation, choosing eco-friendly options, community led travels or finding eco-friendly hotels on a budget friendly level, finding natural resources in the local area, etc.). In addition, more knowledge is needed in order to use AI: "providing much information and options about it" (Respondent J_LT). These ideas come from their education and curiosity to learn more. Thus, one should state that the development and education regarding AI and sustainability should be intensified. Scientific literature also emphasises that various actors in the tourism sector, especially smaller ones, are still lacking AI and other modern digital technologies to influence sustainable practices (Shuai & Karia, 2024).

Research limitations and future research opportunities. The interviews with 11 respondents are providing only the primary insights, however, they help to notice particular realia and behavioural trends. Future research could be performed at industrial, business and consumer levels in different socio-economic and cultural contexts, including the preparation and scope of tourism service providers to apply AI in forming sustainable consumer behaviour; adaptation of different AI tools in different tourism services (including tourism development in peripheral regions); analysis of attitudes and behaviour of the individuals of different generations towards AI-driven tourism services and sustainable tourism practices (including the factors and prerequisites of AI application in shaping sustainable behaviour). In order to maintain a statistical reliability, qualitative and quantitative research methods should be combined. There is a need for a longitudinal study as well, to analyse the changes of AI role in shaping sustainable behaviour among different generations and contexts.

6 Conclusions

1. Scientific literature emphasises various advantages of AI in shaping sustainable behaviour of the consumers of tourism services, including resource optimization and environmental protection, which covers AI-powered environmental monitoring, optimizing resource usage, waste management, protecting sensitive ecosystems, sustainable transportation; enhancing traveller experiences and promoting responsible behaviour

which includes personalized recommendations, AI-powered chat-bots, smart tourism apps, virtual tours; strategic planning and decision-making, which covers tourism demand forecasting, data analysis, monitoring tourist flows, building smart cities and enhancing destination competitiveness.

2. However, exploratory empirical research, based on the interviews with the respondents, which are born between 1990 and 2000 and residing in Lithuania and India, revealed that despite the significance of sustainability in respondents' lives, AI application in shaping a sustainable behaviour of the respondents is still very limited or unknown, including AI opportunities in the tourism sector in general. Since the respondents showed a willingness to use AI while discovering sustainable tourism services, both science and business representatives should search for the adequate and complex ways to employ AI in the tourism sector on purpose to increase sustainability.

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THE TAX COMPETITION IN TURBULENT TIMES: THE RACE TO THE BOTTOM IN EUROPEAN OECD ECONOMIES

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This paper examines the effectiveness of competitive tax policies in attracting foreign direct investment (FDI) within European OECD economies, considering the role of corporate income tax as a key instrument. Beyond statutory tax rates, the analysis incorporates tax base breadth and tax incentives, which are crucial tools employed by national governments to influence FDI flows, more specifically, effective average tax rate (EATR). This resulted in a "race to the bottom" for tax competitiveness. However, the success of these competitive tax policies must be assessed in the context of economic turbulences, including the 2007–2009 Global Financial Crisis, the 2010–2014 Debt Crisis, and the 2020–2021 Pandemic crisis. The research analyses whether the impact of tax competition on FDI diminishes in times of turbulent environment. To address this, the research employs subsamples covering different (crisis) periods, applying Panel-Corrected Standard Errors (PCSE) to ensure robust estimation. Findings indicate that the effectiveness of tax competition in attracting FDI declines during crises, suggesting that economic shocks have a stronger influence on FDI inflows than tax policy changes. This highlights the need for policymakers to consider broader macroeconomic stability alongside fiscal incentives when designing tax policies to attract investment.

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1 Introduction

The integration of the EU's single market and globalization has reinforced the four fundamental freedoms, particularly enhancing capital mobility (Radaelli & Kraemer, 2008; Genschel & Schwarz, 2011; Rixen & Schwarz, 2012; Glavaški & Beker Pucar, 2020). This has intensified tax competition, as government adjust tax policies – primarily by lowering rates – to attract foreign direct investment (FDI) and retain mobile tax bases (Cozmei, 2015). A key aspect of this competition is "race to the bottom" (Devereux et al. 2002). While statutory tax rates shape investment decisions, corporate tax system also include investment incentives, deductions, depreciation allowance, and credits, creating gaps between nominal and effective tax rates (Gale & Samwick, 2014; Bénassy-Quéré et al. 2005). To enhance FDI attractiveness, governments frequently reduce not only statutory rates but also modify tax bases, thereby lowering effective average tax rate (EATR) (Auerbach, 2013; Egger et al. 2009; Heshmati et al. 2010). For investors, the effective tax burden on corporate profits is a decisive factor in location choices (Barrios et al. 2014; Devereux & Sørensen, 2006). Consequently, tax competition has become a key determinant of cross-border capital flows, influencing national policies and global investment patterns (Glavaški et al. 2022; Beljić et al. 2023).

The effectiveness of tax competition in attracting foreign direct investment (FDI) has been further challenged by series of negative external shocks, including the 2008 Global Financial Crisis, the 2010-2014 Sovereign Debt Crisis, and the 2020 Pandemic Crisis (Avi-Yonah, 2019; Genschel & Seelkopf, 2016; Eroglu, 2015; Elali, 2009;**). These crises have significantly disrupted economic stability, leading to slower economic growth, rising unemployment, and a decline in FDI flows (Beljić & Glavaški, 2021; Stojkov et al. 2022). As a result, tax policies that were effective in pre-crisis periods may no longer yield the same results in stimulating investment flows. Given these complexities, this paper focuses on examining how tax competition strategies evolved 22 European OECD economies between 1998-2021, with particular emphasis on impact of the crisis mentioned and the sensitivity of FDI movements in crisis conditions. This goal is analyzed using Panel-Corrected Standard Errors (PCSE)** estimator to encompass heteroskedastic, autocorrelated and/or contemporaneously correlated disturbances**. Namely we applied PCSE method to analyze EATR changes impact on FDI inflows for**

four periods: (a) the original sample for the period 1998-2021 and three subsamples (b) the first, covering a relatively stable period in terms of crises from 1998 to 2007; (c) the second, covering global instabilities, as well as the Sovereign Debt Crisis that affected Eurozone (2008-2014); the third, covers the period including the Pandemic Crisis (2015-2021)**. This study aims to provide a deeper understanding of the resilience and adaptability of tax competition as a tool for attracting FDI in times of economic turbulence. Thus, the main hypotheses of the paper are:**

Hypothesis (*H1*): *There is a negative relationship between EATR and FDI inflows in European OECD economies in the period 1998–2021.*
Hypothesis (*H2*): *The impact of EATR on the FDI inflow in the long run for EU economies is lower in time of economic turbulences (economic crisis).*
The reminder of the paper is organized as follows, after the Introduction part, the Section 2 represents theoretical background about economic turbulences – crisis condition and EATR and FDI changes. Section 3 explained used methodology. In Section 4 the main results of the paper are presented. In the last part, concluding considerations were made.

2 Theoretical framework: EATR and FDI in time of crisis

Starting in 2008, European OECD economies experienced economic turbulence in the form of the Global Financial Crisis of 2008-2009; then, the Eurozone sovereign debt crisis of 2010-2014 (especially the economies of the PIIGS) and finally the Pandemic Crisis (2020-2021). The Global Financial Crisis represents one of the most severe economic crises since the Great Depression of 1929 to date. It began in the US with the collapse of the subprime mortgage market. Shortly thereafter, the crisis spread from the financial market to the real sector through a domino effect. The crisis quickly spread globally, causing a decline in economic activity, rising unemployment, and a decline in investment. The public debt crisis in the Eurozone followed due to of the Global Financial Crisis, when many Eurozone economies, especially the peripheral economies of the eurozone – the PIIGS (Portugal, Ireland, Italy, Greece, Spain) faced difficulties in servicing their (public) debts. The last in the series of crises of the observed period is the Pandemic Crisis. It began in late 2019 with the emergence of the COVID-19 virus (health shock) and lasted throughout 2020 and 2021. This crisis episode had far-reaching global effects with a complex

cause-and-effect chain, including repercussions on various aspects of society and the economy (Beker Pucar, 2024). Therefore, governments responded with a combination of monetary and fiscal measures, which mitigated the initial shocks, however, the long-term consequences of increased inflation, uncertainty in the labor market, and changes in global investment flows are still present.

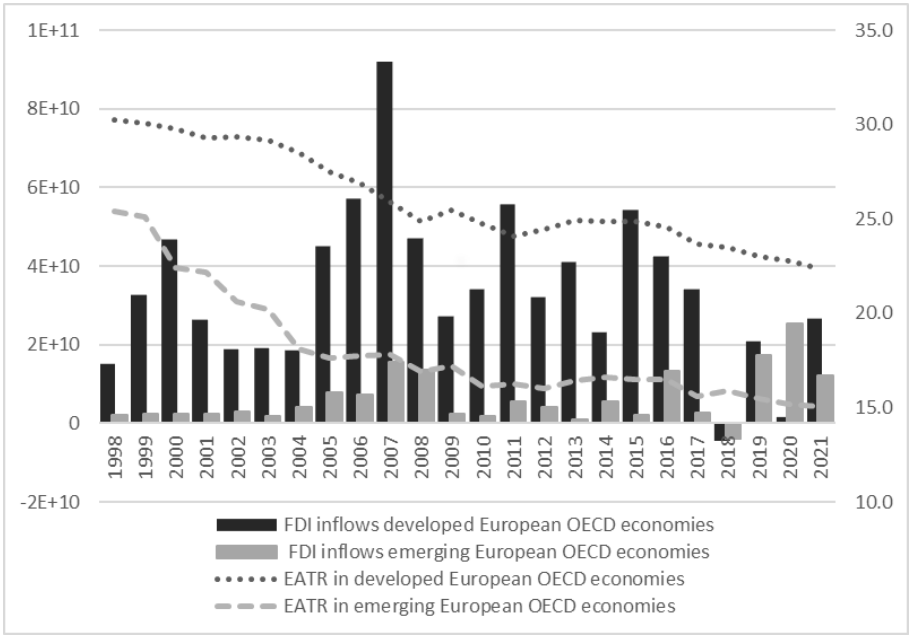

Figure 1: FDI inflow trends and EATR changes in European OECD economies in the period 1998-2021

Source: authors' view based on *World Bank data.*

Figure 1 shows the FDI inflows for developed European OECD economies and emerging economies in the period from 1998 to 2021, which includes the analyzed crisis episodes. Up until 2007, when FDI inflows peaked (seen on the primary axis), most of the economies under observation recorded a rise in FDI inflows. This upward trend in FDI inflows was accompanied by a decline in EATR in both groups of European OECD economies. Namely, from the beginning of the observed period until 2007, EATR decreased (from 27.9 on average in 1998 to 21.8 in 2007). After 2008, the trend of declining EATR (shown on the secondary axis) persisted due to the "race to the bottom" for tax competitiveness. However, FDI inflows decreased significantly in the years of the crisis. A decrease in FDI inflows, as well as FDI

outflows, was recorded in 2008 and 2009, because of the outbreak of the Global Financial Crisis. This was followed by a short-term growth of FDI inflows, given that some European economies (Eurozone members) were also affected by the Sovereign Debt Crisis, which again led to a decrease in FDI inflows. In 2018, most of the observed economies recorded FDI outflows, due to the tensions between USA and China, as well due to BREXIT. The Pandemic Crisis led to a decrease in FDI inflows too, especially in emerging economies. As part of the descriptive analysis, Figure 1 shows the movement of FDI, therefore, European OECD economies were affected by a series of crises in the observed period that caused a decline in FDI inflows, regardless of the measures taken by economic policymakers that implied a decrease in EATR (Figure 1).

3 Methodology

For the purposes of the conducted research, and with the aim of obtaining robust estimates, the Panel-Corrected Standard Errors (PCSE) method was used. Namely, Beck & Katz (1995) recommend the use of this model, considering that it allows for the control of heteroscedasticity, and is also resistant to cross-sectional dependence – which leads to more precise estimates. The PCSE method is adequate since it is robust in panels with a shorter time dimension. The model specification can be written as follows:

$$y_{it} = b_0 + b_1 X_{it} + b_2 D_i + \mu_i + \Lambda_t + u_{it} \quad (1)$$

where y_{it} is the dependent variable for economy *i* and time *t*. X_{it} represents the independent determinants for *i* at time *t*. D_i represents an artificial variable in the model used to account for groups of 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.

The estimated model(s) can be written as follows:

$$fdi_{it} = \alpha + efec_{it}\beta_{it} + u_{it} \quad (2)$$

where fdi_{it} represents the FDI inflow expressed in dollars (source: World Bank data), while $efec_{it}$ represents the EATR (source: EU project effective tax levels using the Devereux/Griffith methodology).

4 Results and discussion

In the chapter that includes a descriptive analysis of the key variables, it is shown that the European OECD economies were affected by the Global Financial Crisis (2008-2009), the Eurozone Sovereign Debt Crisis (2010-2014) – especially the PIIGS economies, and the Pandemic Crisis (2020). National governments adjusted fiscal strategies to mitigate the recessionary effects of the crisis. Namely, by using tax incentives in the form of lowering the EATR (as one of the key instruments for attracting FDI), economic policymakers sought to attract FDI – thereby directly affecting economic growth. However, given FDI is the one most vulnerable to crisis situations, the question of whether tax policy measures are efficient in drawing the FDI into turbulent times emerges (Figure 1). To demonstrate the efficacy of taxation policies in turbulent times—that is, the achievement of tax competitiveness for the purpose of attracting FDI—the period of crises is therefore incorporated into the model(s). Due to the spillover effects of the aforementioned crises on European OECD economies, the original sample (1998-2021) is divided into three subsamples: the first, covers a relatively stable period in terms of crises from 1998 to 2007; the second, covers global instabilities, as well as the public debt crisis that affected Eurozone (2008-2014); the third, covers the period that includes the Pandemic Crisis (2015-2021).

Table 1: Homogenous results for PCSE for 22 European OECD economies in four (sub)periods

Sample (a)	22 European OECD economies for homogenous coefficients from 1998-2021		
Dependent variable: **FDI**	Coefficient β_i'	PCSE Standard Error	*p*-value
EATR	-1.39	3.30	0.000
Constant	-8.45	7.10	0.234
R^2	0.0238		
Wald chi2	17.76		
Number of observations	524		

Sample (b)	**22 European OECD economies for homogenous coefficients from 1998-2007**		
Dependent variable: **FDI**	Coefficient β_i'	PCSE Standard Error	*p*-value
EATR	-1.58	6.00	0.008
Constant	-1.55	1.12	0.165
R^2	0.0321		
Wald chi2	6.96		
Number of observations	216		
Sample (c)	**22 European OECD economies for homogenous coefficients from 2008-2014**		
Dependent variable: **FDI**	Coefficient β_i'	Standard Error	*p*-value
EATR	-1.55	4.37	0.000
Constant	-8.24	7.44	0.268
R^2	0.0289		
Wald chi2	12.51		
Number of observations	154		
Sample (d)	**22 European OECD economies for homogenous coefficients from 2015-2021**		
Dependent variable: **FDI**	Coefficient β_i'	Standard Error	*p*-value
EATR	-1.13	4.30	0.009
Constant	-3.86	1.13	0.733
R^2	0.0999		
Wald chi2	6.89		
Number of observations	154		

Source: Authors' own calculation based on *Stata 15*.

The homogeneous coefficients obtained using PCSE are shown in Table 1 (panel (a); (b); (c); (d)). Based on the results obtained, it can be concluded that in all four analyzed (sub)samples a statistically significant negative relationship was found between the EATR and FDI. Such a relationship is expected since it is in line with economic theory and is also in line with previously obtained empirical results (Glavaški et al. 2022; Beljić et al. 2023). The analysis of the whole sample, encompassing both stable periods and turbulent times, reveals a negative relationship of -1.39 between EATR and FDI (confirmation of Hypothesis *H1*) (Table 1, panel (a)). However, to examine the impact of turbulent circumstances on tax competition's capacity to attract FDI, we divided the original sample into three distinct subsamples. As previously pointed out, there is a negative relationship between EATR and FDI throughout a particularly stable, crisis-free period. This relationship is also greatest (-1.58; Table 1, panel (b)), indicating that FDI is most sensitive to fluctuations in EATR. On the other hand, when crisis conditions such

as the Global Financial Crisis (2008-2010) and the Sovereign Debt Crisis (2010-2014) are incorporated into the model, the coefficient is lower (-1.55; Table 1, panel (c)), suggesting that tax competitiveness's ability to draw in FDI is weakened during a crisis. Furthermore, it was investigated how sensitive FDI was to variations in EATR levels, when an exogenous health shock raised. Namely, statistically significant negative relationship was detected in the period covering the Pandemic Crisis (-1.13; Table 1, panel (d)), however it is the smallest compared to the other analyzed periods (Table 1, panel (b); (c)). This suggests the conclusion that policy makers that use tax competition for attracting FDI have less maneuver when turbulent years are considered. Namely, the obtained estimates show that a decrease in EATR by 1% leads to an increase in FDI by 1.58% in the pre-crisis period, while in crisis circumstances a decrease in EATR by 1% leads to a smaller increase in FDI of 1.55% and 1.13% (respectively). The above leads to the conclusion that FDI is more sensitive to crisis circumstances than to changes in tax strategies (i.e. achieving tax competitiveness) (confirmation of Hypothesis *H2*).

5 Conclusions

Over the past two decades, European OECD economies have seen exogenous shocks that have impacted on tax strategies and their effectiveness in luring FDI. Firstly, economic policymakers faced the Global Financial shock in 2008, followed by the Sovereign Debt Crisis in 2010-2014, especially in Eurozone members. Secondly, the pandemic-induced shock that led to border closures, difficult cooperation, high and rapidly rising uncertainty during the Pandemic Crisis, while FDI flows were significantly affected. Therefore, the effect of the EATR on FDI inflows in European OECD economies is examined in this research, with particular attention to the relationship when years of economic turbulence are included in the model. The research findings suggest that the influence of EATR decreases on FDI is diminished during crisis periods compared to years free from external shocks. Namely, the main conclusions of the paper are as follows: (a) The results of the Panel-Corrected Standard Errors (PCSE) model on a sample of 22 European OECD economies over the period 1998-2021 confirm that there is a negative relationship between EATR and FDI inflows. (b) In a sample of a generally stable period, the PCSE indicates that the relationship is most pronounced, demonstrating that tax competition possesses the greatest capacity to attract FDI. (c) Incorporating economic disturbances such as the Global Financial Crisis and Sovereign Debt Crisis

into the model reveals that policymakers' options for employing tax competition are constrained. (d) Furthermore, when the Pandemic Crisis is incorporated into the model, the capacity of tax competition to attract FDI is diminished, as the flow of FDI is primarily influenced by the effects of the crisis.

The results demonstrate that economic policymakers' capacity to implement current tax policies in the context of attracting FDI during times of crisis is constrained by exogenous forces. Specifically, when crisis conditions worsen, tax policy' capacity to draw FDI declines since, during periods of economic turbulence, the crisis—rather than tax policies—has the greatest impact on FDI flows. Policymakers ought to consider about broadening their strategy for luring FDI to strike a balance between tax competitiveness and macroeconomic stability, especially during turbulent times. This could entail combining competitive tax rates with non-tax incentives like worker quality, regulatory efficiency, and infrastructure upgrades, which remain to be beneficial even in situations where fiscal resources are limited. Furthermore, the adoption of flexible and adaptive tax structures – capable of to economic cycles – can help mitigate the adverse effects of exogenous shocks. Such strategies would allow governments to preserve the attractiveness of their tax system while enhancing resilience to future crisis, thereby sustaining FDI inflows even when traditional tax competition loses its efficiency.

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From Insight to Impact: How AI Tools Transform Managerial Practice in Czech Companies

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This study investigates the practical applications of artificial intelligence (AI) in managerial work, with a focus on how tools such as large language models (LLMs) support the personal and professional development of managers. It explores how AI is used for decision-making, information analysis, and communication, and assesses its perceived impact on managerial knowledge, skills, and productivity. The research combines a comprehensive literature review with empirical data from a structured survey of 42 managers in Moravian companies, primarily in the Czech Republic. The study evaluates the frequency, purpose, and tools used in AI-assisted management practice. AI tools are frequently used by managers, especially for information summarization, meeting preparation, and text generation. ChatGPT (GPT-4) is the dominant tool, with most respondents reporting weekly or daily use. The majority perceive AI as beneficial, with an average Likert score of 7.86 regarding its positive impact on performance. Limitations include the localized sample, rapid research timeframe, and fast-paced AI evolution, which may affect long-term generalizability. The study offers practical insights into how AI enhances managerial routines and leadership development. This paper provides rare, localized empirical evidence on AI adoption in management, contributing to a fast-growing global research area.

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1 Introduction

The rapid advancement of artificial intelligence (AI) technologies – particularly large language models (LLMs) – is significantly transforming how decisions are made and how leadership is exercised in contemporary organizations. In this dynamic environment, managers are increasingly expected to leverage AI tools not only to streamline operations but also to develop their soft skills, enhance strategic thinking, and improve personal productivity.

This study aims to explore the practical applications of artificial intelligence (AI) in management, focusing on how tools like large language models (LLMs) support the personal and professional development of managers through decision support, data analysis, and coaching. By capturing real-world insights from Czech managers, it contributes to the global conversation on human-AI collaboration and highlights both the benefits and challenges of AI integration in leadership roles.

2 Theoretical Background / Literature Review

In the era of digital transformation, artificial intelligence (AI) is fundamentally reshaping managerial functions and leadership paradigms. Several authors emphasize the transformative role of AI in strategic leadership. Huber and Alexy (2024) argue that AI redefines leadership by enabling data-driven decision-making, shifting from intuition-based leadership to an analytical approach supported by predictive models. Similarly, Oppioli et al. (2023) provide a structured review confirming AI's capacity to improve managerial decisions by offering faster, more accurate insights based on data modelling. In the context of leadership development, Bhusan and Jain (2024) propose that AI tools, such as LLMs, serve not only as task enhancers but also as catalysts for developing emotional intelligence and reflective leadership. Dwivedi (2025) supports this view, advocating for the integration of emotional and artificial intelligence in fostering human-AI synergy in executive roles. Organizational agility is another recurring theme. Atienza-Barba et al. (2024) analyse how AI enhances agility by improving adaptability and responsiveness in fast-changing business environments. This aligns with Arar et al. (2025), who, through an integrative systematic review, show that AI contributes significantly to leadership practices across educational and corporate sectors by augmenting planning and forecasting capabilities. A more empirical perspective is offered by Jaboob et al.

(2025), who explore how digital leadership mediates the successful adoption of AI in strategic decision-making. Karakose and Tülübas (2024) also note that the use of AI in leadership – initially observed in school management – extends effectively to business settings, especially for improving situational awareness and data literacy among managers. From a bibliometric standpoint, studies by Pacheco-Velázquez et al. (2023) and Mesa Fernández et al. (2022) indicate a rising academic focus on AI's application in management, with keywords such as leadership, decision support, and organizational intelligence showing exponential growth since 2020. Patra et al. (2024) confirm this through network analysis, identifying a strong trajectory of AI research in business contexts. Finally, several studies examine the practical use of specific tools. Akpan and Razavi (2025) highlight the educational shift from traditional simulations to AI-powered generative tools in business schools, signalling a parallel evolution in professional settings. Nguyen and Shaik (2024) illustrate how localized AI (like ChatGPT) improves corporate leadership by enhancing real-time language support, coaching, and cross-cultural communication. Together, these studies affirm that AI is not only reshaping the tools available to managers but also the very nature of leadership itself. The literature provides a robust theoretical lens for understanding the findings of this paper, particularly in relation to the Czech business environment.

3 Methodology

The methodology of the paper combines both theoretical and empirical approaches. First, the authors conducted a comprehensive literature review to establish the theoretical foundation concerning the use of artificial intelligence (AI) in management. This was followed by empirical survey-based research, targeting managers in Moravian companies. The research question (RQ1) has been formulated: How are artificial intelligence (LLMs) tools used (frequencies, reasons, tools) by managers in Moravian companies, and what is their perceived impact on managerial knowledge, skills, and productivity?

The data source is a Google forms survey conducted in early 2025 with the help of students of the Bachelor of Economics and Management at the Moravian Business College Olomouc (MVSO). The survey is aimed at young respondents with a strong interest and engagement in management. The structure of the data obtained can be characterised as follows: the 42 respondents were mainly young managers from the

Olomouc region (Czech Republic), of whom 64% were women and 36% men. 31% of the respondents work in a family business. 64% work in a medium-sized company, 19% in a small company and 12% in a large company. 52% of respondents work in a global, multinational or foreign company, 48% in a national, state, regional or own company. In terms of branch, 31% of respondents focus on marketing, 19% on finance and 10% on trade. In terms of interest in different areas of management, most respondents are interested in marketing management (64%), financial management (55%), strategic management (41%), international management (29%) and human resources management (27%). Less than a quarter of respondents are interested in other areas.

4 Results

The chapter presents the main findings of the research focused on the use of artificial intelligence (LLMs) in the management of Moravian companies. Based on empirical data from a questionnaire survey of young managers, it provides an overview of the frequency and reasons of using AI tools, the most common tools in management practice, and the perceived impact of AI on respondents' knowledge, skills and productivity. The results provide valuable insight into the current state of AI adoption in the managerial environment and help identify the key benefits and limitations of these technologies. These findings are visually supported by graphs illustrating key trends and relationships in the use of AI in management.

The pie chart (see figure 1) illustrates how often individuals use artificial intelligence tools such as ChatGPT, Grammarly, and DeepL. The majority of respondents (43%) use these tools several times a week, while 19% use them daily. A smaller portion (10%) reports using AI tools several times a day. Occasional users account for 14%, whereas those using AI tools once a week and several times a month each make up 7% of the responses. Notably, none of the respondents indicated that they never use AI tools. The results show a relatively high frequency of use of AI tools, with almost 1/3 (29%) using these tools once or more per day. More than 3/4 (79%) of respondents stated they use AI at least once a week.

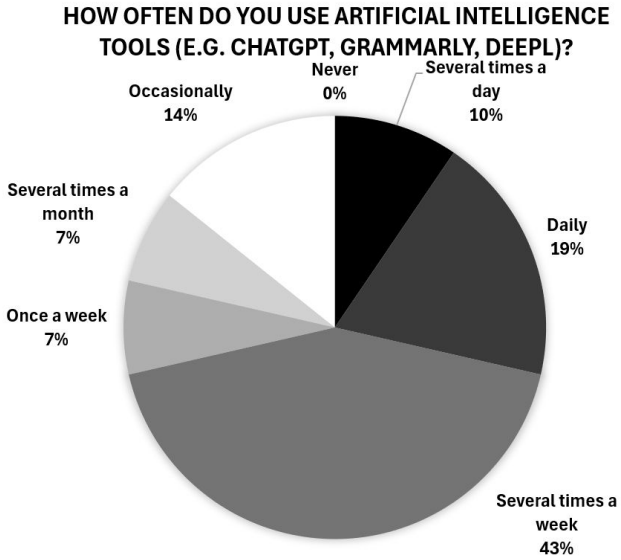

Figure 1: Frequency of AI Tool Usage
Own processing

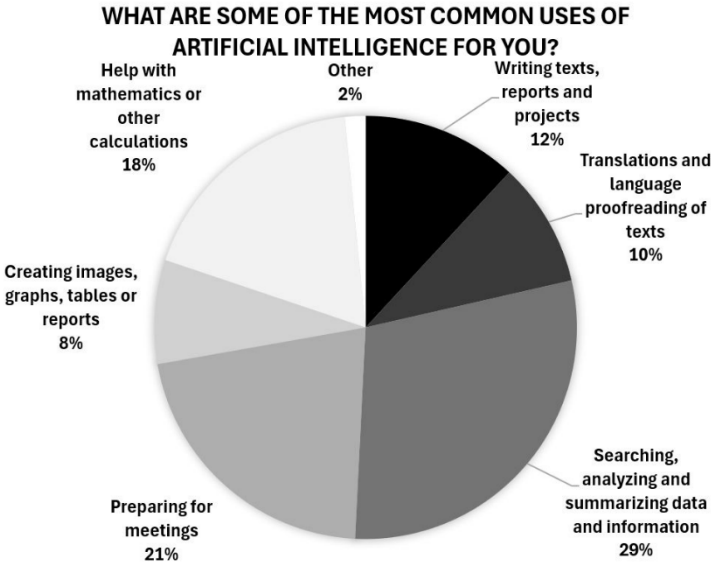

Figure 2: Common Uses of Artificial Intelligence
Own processing

The pie chart (see figure 2) illustrates the most common applications of artificial intelligence among users. The primary use is for searching, analysing, and summarizing data and information (29%). Preparing for meetings is another significant use case, accounting for 21%. AI is also commonly used for mathematical calculations (18%), writing texts, reports, and projects (12%), and translation or language proofreading (10%). Other uses include creating images, graphs, tables, or reports (8%), while a small portion (2%) falls under the "Other" category. In the "Other" category, respondents cited its use for learning, explaining unfamiliar concepts and providing practical examples or case studies.

The pie chart (see figure 3) displays the distribution of AI tools and language models used by respondents. The dominant tool is ChatGPT (OpenAI – GPT-4), utilized by 70% of users. Other notable AI tools include DeepL Write/Translator (8%), Grammarly (4%), DALL·E (5%), and Google Gemini (3%). Additionally, Microsoft Copilot (3%), DeepSeek (3%), and Notion AI (2%) are in use. A smaller percentage (2%) of users employ Elicit, NotebookLM, and Litmaps for AI-related tasks.

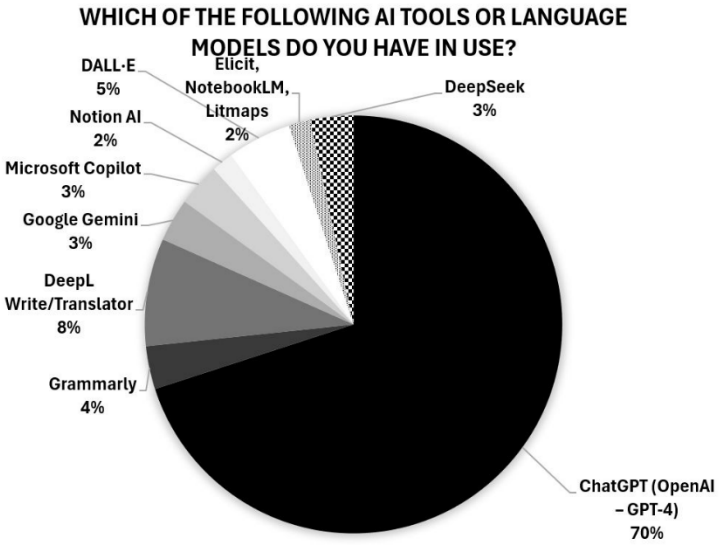

Figure 3: AI Tools and Language Models in Use
Own processing

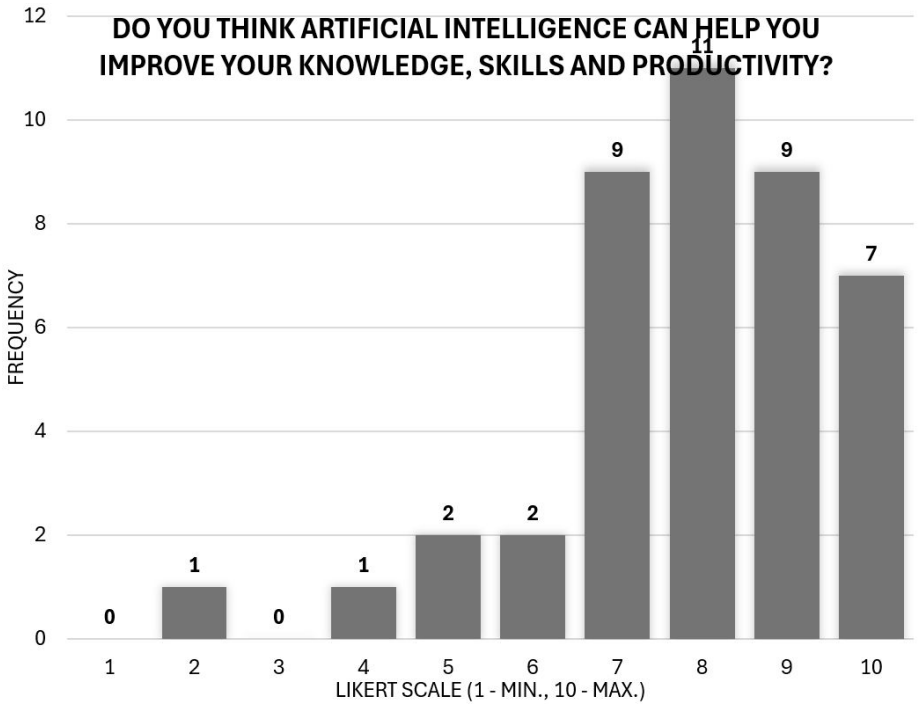

Figure 4: Perceived Impact of AI on Knowledge, Skills, and Productivity
Own processing

The bar chart (histogram) illustrates respondents' opinions on whether artificial intelligence can enhance their knowledge, skills, and productivity, using a Likert scale from 1 (minimum) to 10 (maximum) – see figure 4. The highest frequencies are observed at 7 (11 responses), 8 (9 responses), and 9 (9 responses), indicating strong agreement with AI's positive impact. Additionally, 10 (7 responses) further supports this sentiment. Lower ratings (1-4) received minimal responses, with only a few respondents rating AI's impact below 5. This suggests an overall positive perception of AI's benefits in improving knowledge and efficiency.

Using fuzzy logic, we can approximate the probabilistic allocation:

- Mostly agree (7-9) → 0.75 (dominant affiliation)
- Strongly agree (9-10) → 0.25 (partial affiliation)

The mean of 7.857 means that the respondent believes that artificial intelligence will help improve knowledge, skills and productivity, but not with complete certainty.

A typical respondent of the study is a young manager (woman) from the Olomouc region, working in a medium-sized company with international operations (not family-owned) and with a professional focus on marketing management. This manager uses ChatGPT LLM several times a week to search, analyse and summarise data and information, and is particularly confident that AI will help her improve her knowledge, skills and productivity.

5 Discussion

The results of the study clearly confirm that artificial intelligence (AI) tools are increasingly embedded in the daily managerial practices of young Czech professionals, particularly in tasks involving information processing, decision support, and communication. This high adoption rate (with 79% using AI at least weekly and 29% daily) aligns with broader global findings on the integration of AI in organizational workflows. ChatGPT (GPT-4) emerged as the dominant tool, which reflects trends discussed by Nguyen and Shaik (2024), who emphasize the utility of conversational AI for leadership adaptation in dynamic corporate contexts. This dominance also supports the claim by Akpan and Razavi (2025) that generative AI is transforming professional decision-making and business education by enabling fast, interactive analysis. The primary functions of AI – data search, meeting preparation, and report generation – mirror findings from Mesa Fernández et al. (2022) and Patra et al. (2024), who note that these are among the most rapidly growing application areas in management science. The heavy reliance on natural language processing tools (e.g., ChatGPT, Grammarly, DeepL) supports Pacheco-Velázquez et al. (2023), who emphasize the increasing convergence between communication-based leadership and AI tools.

Regarding perceived impact on knowledge, skills, and productivity, the average Likert score of 7.857 suggests cautious optimism. Most respondents view AI as beneficial, though a minority remains uncertain. This nuanced view is consistent with Dwivedi (2025) and Bhusan and Jain (2024), who both suggest that AI can enhance human capabilities, but its long-term impact on leadership development depends on critical reflection, emotional intelligence, and training. Additionally,

Huber and Alexy (2024) point out that the shift to AI-supported strategic leadership demands a rethinking of traditional leadership models. Our results, particularly the use of AI for meeting preparation and strategic communication, affirm this evolution from task execution to AI-augmented cognition. Finally, Polat et al. (2025), Arar et al. (2025), and Camilleri (2024) argue that ethical and contextual considerations are increasingly relevant. Camilleri emphasizes that AI governance must align with principles of social responsibility and transparency, especially in leadership contexts where decisions affect broader organizational ecosystems.

6 Conclusions

The research confirms that AI tools play a significant role in managerial tasks, particularly in data analysis, preparation for meetings, and decision-making support. AI adoption is relatively high, with most managers using it at least weekly. While ChatGPT is the dominant tool, other AI applications (e.g., DeepL, Grammarly, and DALL·E) contribute to specific management functions. There is strong agreement (but not absolute certainty) that AI enhances knowledge, skills, and productivity. The study highlights the practical implications of AI in management.

RQ1 has been answered like that: The findings show that managers in Moravian companies frequently use AI tools, particularly for data handling and communication – 79% use AI weekly, and 29% daily. ChatGPT (GPT-4) is the dominant tool (70%), followed by DeepL, Grammarly, DALL·E, and others. Main uses include information analysis (29%), meeting preparation (21%), and writing or translation tasks. The average Likert score of 7.857 indicates a strong, though not absolute, agreement that AI improves managerial knowledge, skills, and productivity.

The originality of this study lies in its combination of a current theoretical framework with primary empirical data gathered from practicing managers in Czech companies. It contributes uniquely to the emerging field of AI-enhanced management by providing localised insights into how AI tools, particularly large language models, are integrated into everyday managerial activities. The findings have practical implications for both practitioners and educators, as they highlight not only the frequency and purpose of AI use but also managers' perceptions of its impact on productivity, decision-making, and skill development. However, the study's

limitations include a small and regionally concentrated sample, a short research timeframe, and the rapidly evolving nature of AI technology, which may limit the long-term relevance of specific tools mentioned. Future research should adopt broader and comparative designs, explore changes over time, and assess the ethical, cultural, and psychological dimensions of AI use in leadership and organizational contexts.

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Revolution in Project Management: Focusing on Sustainability and AI

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In recent years, sustainability has become a pivotal focus in several areas, including project management, driven by the need to address environmental, social, and governance (ESG) considerations. This journal explores the integration possibilities and practices of sustainability in project management, emphasizing the role of Industry 5.0 and artificial intelligence (AI) in enhancing ESG outcomes through a systematic literature review of currently accessible academic literature. This literature review, following PRISMA guidelines, addresses 4 research questions. Findings reveal a scarcity of relevant literature, indicating lack of popularity among researchers. Industry 5.0, characterized by the collaboration between humans and advanced technologies, offers a transformative approach to project management by fostering innovation and sustainability. AI, with its capabilities in data analysis, predictive modelling, and decision support, plays a crucial role in supporting ESG initiatives. By leveraging AI, project managers can ensure that projects align with sustainability goals, optimize resource utilization, and enhance transparency and accountability. The authors dive into the synergies between Industry 5.0's pillars and AI, highlighting their potential to drive sustainable project management practices and contribute to long-term value creation for organizations.

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1 Introduction

Project management has become indispensable across industries for successful project delivery. Regardless of sector or project size, project management methodologies (PMM) enhance the likelihood of meeting goals (Martens & Carvalho, 2024). Researchers widely concur that suitable PMMs boost project success. The integration of sustainability in project management is essential for addressing ESG considerations. Industry 5.0 and AI offer transformative potential by fostering innovation, optimizing resources, and enhancing transparency (Chawla et al., 2018). By leveraging these technologies, project managers can drive sustainable practices, contributing to long-term value creation and aligning with organizational sustainability goals. Industry 5.0 represents a significant evolution in industrial practices, emphasizing human-centricity, sustainability, and resilience.

There is only fragmented knowledge regarding implemented practice of Industry 5.0 techniques in organizations. The goal of this paper is to address the fragmented knowledge regarding the implementation of Industry 5.0 techniques in project management. Specifically, it aims to identify and fill the existing gap in academic literature related to these techniques, as examined in Web of Science and Scopus. The research follows PRISMA guidelines (Page et al., 2021) to ensure a systematic, transparent, and rigorous process, focusing on four clear research questions. The study's objective is to provide comprehensive knowledge on the subject. This literature review serves as a foundational reference for future research on the application of Industry 5.0 in project management across various industries. Focusing on keywords during search,

- Industry 5.0 and/in project management
- Sustainability and/in project management
- ESG and/in project management
- AI and/in project management

the result for number of literatures (including articles, review articles, books, book chapters, conference papers, conference reviews) found in Web of Science is 166, in Scopus 177, all together 255 without duplicates. Out of these around 25% of articles are relevant to this topic after a systematic literature review, which means the topic is not yet popular among business and economists' researchers, moreover there are

several of web articles generally speaking about Industry 5.0 or sustainability and AI, those are not based on scientific research and analyses. As a result, 4 research questions are discussed, including the benefits, challenges, opportunities of Industry 5.0 on the project management field of expertise.

The selection and analysis of articles was guided by 4 research questions determined, found in Table 1. During the search and analysis of academic literature, the individual articles were manually reviewed and searched for relevant content related to the research questions.

Table 1: Research questions

#RQ1	How pillars of Industry 5.0 can be integrated in project management?
#RQ2	How does the integration of sustainability practices impact the success of project management?
#RQ3	How does the adoption of AI impact project management?
#RQ4	What challenges will bring Industry 5.0 and AI in the project management area?

Source: Own Editing (2025)

2 Theoretical Background / Literature review

A project methodology is like a detailed instruction manual for project managers, offering step-by-step guidance on how to run a project, whereas an approach is more like a general strategy or plan without as much specific detail. The definition of project management methodology for this study is taken from A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Sixth Edition (Project Management Institute [PMI], 2017, p. 28), which states that "A methodology is a system of practices, techniques, procedures, and rules used by those that work in a discipline."

„The application of technology in Industry 5.0 based on a constant flow of information provides an increase in opportunities for process efficiency" (Patalas-Maliszewska & Losyk, 2024, p.2), therefore, it seems reasonable to review the related literature to examine the impacts during managing projects. Shortlisted relevant articles (Hein-Pensel et al., 2023; Zuzek et al., 2021; Taboada et al., 2023; Gibbin et al., 2023; Gärtner et al., 2023) mention several approaches and objectives of Industry 5.0, highlighting its focus on holistic, sustainable, and human-centered value creation, bringing in fore social and ecological objectives (Marcelino-Sádaba et al.;

2015; Silvius & Schipper, 2016; Silvius, 2017; Ali et al., 2016). We've collected the main characteristics of Industry 5.0's sustainability pillar and AI related to project management.

The literature on the intersection of Industry 5.0, sustainability, and artificial intelligence (AI) in project management reveals several key themes and trends. Industry 5.0 emphasizes human-centric, sustainable, and resilient production systems, leveraging advanced technologies like AI to enhance efficiency and project outcomes (Dubois & Silvius, 2020; Martens & Carvalho, 2016; Martens & Carvalho, 2017). A significant body of research highlights the transformative potential of AI in project management, particularly in improving project performance, resource allocation, risk management, and decision-making processes (Gilbert Silvius, 2017). AI techniques, such as machine learning and predictive analytics, are noted for their ability to provide accurate forecasting, optimize resource use, and enhance project planning and execution (Gibbin et al., 2023; Taboada et al., 2023; Krause et al., 2024; Aladag, 2023).

Sustainability in project management is another critical focus, with numerous studies emphasizing the integration of environmental, social, and economic dimensions into project processes (Kirchhof & Brandtweiner, 2011; Tam, 2013). The literature suggests that sustainable project management practices can lead to improved project success, stakeholder satisfaction, and long-term benefits for organizations and society (Martens & Carvalho, 2024; Keshavarzian & Silvius, 2022; Khalifeh et al., 2020). However, there is a recognized gap between the perceived importance of sustainability and its actual implementation in project management practices (Soares et al., 2023; Soares et al., 2024; Toledo et al., 2023; Vivek et al., 2023). The convergence of AI and sustainability in the context of Industry 5.0 presents opportunities for developing innovative frameworks and methodologies that incorporate both technological advancements and sustainable practices (Zhang et al., 2023; Marques et al., 2023; Ferrarez et al., 2023). This integration aims to create more resilient, efficient and responsible project management approaches that align with broader sustainability goals and the evolving demands of Industry 5.0. (Maphosa & Maphosa, 2022; Hashfi & Raharjo, 2023; Felicetti et al., 2024).

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n summary, the common themes in the articles include the transformative role of AI in enhancing project management processes, the critical importance of integrating sustainability into project management, and the potential of Industry 5.0 to drive innovative and sustainable project management practices.

3 Methodology

The search and selection of literature took place in several steps. A database search was performed through Scopus, and Web of Science. The search was not limited by a specific year of publication but documents till end of 2025 02.28. were examined. Only studies in English were included. Abstracts have been exported, Full texts of relevant articles were read from start to finish. Firstly, the search with the search string yielded 166 articles in Web of Science and 177 in Scopus (Figure 1). Boolean operators used: **'and', 'in'.** After extracting these into excel, applying a filter that removes duplicates received 255 results. Articles were screened by filtering „Industry 5.0", „project management", „Sustainability", „ESG", „AI" related to project management receiving 66. These have been reviewed for relevancy by analyzing the title and the abstract, 189 have been excluded. 9 were categorized as not found and 16 no full text received from author. Finally, 41 articles were listed as suitable, clearly containing project management and Industry 5.0 noted keywords, abstracts and body text. Next step was to analyze the full text of the suitable articles.

In terms of limitations and risks, bias might be adopted from analyzed studies, being aware that this literature review relies on available content and context Many articles tend to highlight positive outcomes of Industry 5.0 provided opportunities, however there are no case studies or qualitative analysis related to proven project success due to a specific Industry 5.0 element or approach, because there is not widely applied in project management yet. While the integration of AI and sustainability in project management offers significant potential, the studies highlight several limitations and risks, including context-specific findings, researcher bias, data quality issues, ethical considerations, resistance to change, and the inability of AI to fully account for human factors. Addressing these challenges is crucial for the successful implementation of innovative and sustainable project management practices.

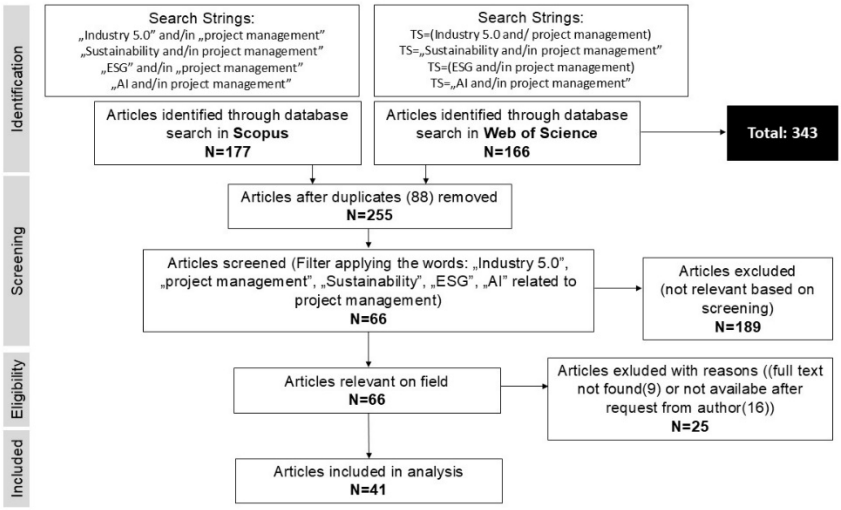

Figure 1: Systematic literature review process, result of findings in Scopus and Web of Science after data clean-up.
Source: Own Editing (2025)

Table 2: List of inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Industry 5.0, Sustainability, ESG and AI related to project management is analyzed	The article text is not in English.
Industry 5.0's main pillar, sustainability is a significant party of the study	There is no full text of the article available. Full text has been requested from authors, but not received within 30 days.
Challenges of AI are examined related to project management	The article does not address any research question closely related Industry 5.0, Sustainability, ESG and AI related to project management is analyzed

Source: Own Editing (2025)

4 Results

In the Industry 5.0 era, companies are leveraging the potential of cutting-edge technologies such as artificial intelligence for more efficient and greener human-centric production (Taboada et al., 2023). Similarly, integrating artificial intelligence into project management methodologies promises enhanced project performance, reaching higher sustainable success. Industry 4.0 emphasizes resilience and its positive ecological and economic impacts, but it often overlooks social dimensions,

such as human-centric approaches. However, Industry 5.0 shifts this perspective, focusing more on the human element in production (Hein-Pensel et al., 2023), also sustainability concepts showcase significant value in construction projects (Stanitsas et al., 2021). Zizic et al. highlight the importance of employee focus and well-being in this new approach, stressing competencies, motivation, and overall human welfare as crucial factors for sustainable digital transformation (Zizic et al., 2022). Similarly, Xu et al. argue that Industry 5.0 complements Industry 4.0 by driving a transition towards a sustainable, human-centric, and resilient industry through research and innovation (Xu et al., 2021).

In a 2021 policy brief, the European Commission describes Industry 5.0 as "more futureproof, resilient, sustainable, and people-centric" concept. (Breque et al., 2021). While there is no universally accepted definition, Industry 5.0 typically refers to a vision of manufacturing and production that integrates advanced technologies such as artificial intelligence, robotics, Internet of Things (IoT), and big data analytics with a strong emphasis on human collaboration and interaction. Based on analysis of the examined literature, Industry 5.0 can be defined as a new concept that focuses on collaboration between humans and machines (Gibbin et al., 2023; Taboada et al., 2023; Krause et al., 2024; Aladag, 2023). The main goal is to create sustainable products and services, while empowering people to fully utilize their skills more efficient and more meaningful (Toljaga-Nikolić et al., 2020; Kostalova & McGrath, 2021), receiving the answer for #**RQ1**.

In a constantly changing project environment that requires high level of adaptability and changing paradigms in management to a more human-centric leadership, Industry 5.0 raised attention on a new project management approach for the future, where every aspect of the PMM is more flexible and people-oriented, due to the popularity of agile project management practices, that are spreading in new industries, not just in software development (Zuzek et al., 2021). The evolution of Industry 5.0 will facilitate more areas of research for project management researchers who are working in human-centric applications, sustainable development, and building resilience in organizations. Majority studies mention the sustainability as core element of Industry 5.0 (Chawla et al., 2018; Ozumba et al., 2018; Rego et al., 2024), receiving answer for #**RQ2**. The integration of sustainability practices positively impacts the success of project management by enhancing project outcomes, improving stakeholder satisfaction, and ensuring long-term benefits.

Sustainable practices help in better resource management, risk mitigation, and alignment with broader organizational goals, leading to more resilient and efficient project execution.

Findings related to #**RQ3** indicate that there is an emerging tendency using artificial intelligence (AI) for project management purposes (Krause et al., 2024; Zuzek et al., 2021; Gibbin et al., 2023), because AI can automate repetitive tasks, provide insights from data analysis, optimize resource allocation, predict project outcomes, generate summaries, tables, facilitate communication and collaboration among team members (Mohite el al., 2024; Dimcheva, 2024; Tarawneh et al., 2024; Sarafanov et al., 2024). By leveraging AI, project managers can streamline workflows, mitigate risks, and achieve better project outcomes. The adoption of AI in project management enhances efficiency by automating repetitive tasks, improving resource allocation, providing accurate forecasting, and aiding in decision-making. It helps in identifying risks, optimizing processes, and ultimately leads to better project outcomes and success.

For project management professionals it will be a challenge to find the balance between structure and flexibility, innovation and discipline, and adaptation to changing circumstances, in terms of ethical using of AI in their projects (Økland, 2015; Friedrich, 2023). Findings to #**RQ4** indicate that companies also face several challenges due to rapid technological developments and innovation projects (Gärtner et al., 2023; Dimcheva, 2024; Sarafanov et al., 2024), they must balance between technological complexity and industrial applicability (Madureira, 2022). Industry 5.0 and AI in project management will bring challenges such as data quality issues, resistance to change, ethical considerations, and the need for skilled personnel to interpret AI-generated insights (Mohite el al., 2024). Additionally, there may be difficulties in fully accounting for human factors and dynamic project environments.

5 Discussion

In the Industry 5.0 era, companies are leveraging advanced technologies like artificial intelligence for efficient, greener, and human-centric production. This integration into project management methodologies enhances project performance and sustainability. Unlike Industry 4.0, which focuses on resilience and ecological impacts, Industry 5.0 emphasizes human-centric approaches and employee well-

being. It aims to create sustainable products and services by fostering collaboration between humans and machines. The European Commission describes Industry 5.0 as a concept that is future-proof, resilient, sustainable, and people-centric. This new approach in project management promotes flexibility, human-centric leadership, and the adoption of agile practices across various industries. The integration of AI in project management automates tasks, optimizes resources, and improves decision-making, leading to better project outcomes. However, challenges such as data quality, resistance to change, ethical considerations, and the need for skilled personnel remain.

The authors' research acknowledges limitations, including potential constraints on generalizability and the influence of biases from prior studies. The authors have addressed a systematic literature review by excluding threats such as search term accuracy and database selection and defining clear inclusion and exclusion criteria. While the authors' study focused on the Web of Science and Scopus databases for its quality, integrating additional databases and grey literature could yield further insights. However, the authors' transparent research design enhances replicability and ensures rigor. Despite its potential, this research faces other limitations that require attention. One key aspect is the appliance of Industry 5.0's pillars and exact AI tools in project management related practical scenarios.

6 Conclusions

In order to increase adaptability and acceptance of technological revolutions and innovative solutions on in project management, it is essential to foster a culture of innovation and collaboration on organizational level. Nowadays, there is a growing interest in exploring the potential of AI to revolutionize PM. Very few researches were conducted to analyze the potential and limitations of AI in this field. New technologies are not limited to manufacturing processes; they also hold promise for improving business procedures like project management (PM). Cutting-edge project management trends emphasize the integration of artificial intelligence (AI). AI is transforming both the nature of projects and how they are managed. While reports suggest that AI enhances PM productivity and quality, there is a lack of literature analyzing AI techniques across PM performance domains. This raises questions about how AI can enhance PM processes and performance, and how future literature will address this topic.

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Assessing Measurable Financial and Sustainability Data for Agricultural Competitiveness

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This paper investigates the availability and applicability of measurable financial and sustainability data critical for assessing the new competitiveness of agricultural entrepreneurs in Hungary and in Poland. The context is part of a larger research, focusing on a rapidly changing global landscape. This study introduces an analysis on the financial differences in 10 years from the 2004-2024 period. It includes recommendations on sustainability indicators such as the Sustainable Return on Equity (SROE), the Sustainable Profitability (%) and the Environmental, Social, and Governance (ESG) index. The larger research employs a mixed-method approach utilizing various robust databases to ensure comprehensive analysis and validity. Through careful examination of how various elements, the study clarifies the basics for financial and sustainability. Furthermore, the findings present a framework designed to facilitate enhanced performance and resilience against economic fluctuations and environmental challenges, ultimately fostering an innovative agricultural landscape that effectively meets modern consumer demands and regulatory standards. This paper is useful to the efforts in all EU Member States, while highlights the necessity for the sustainability indicators besides the financial metrics.

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1 Introduction

The agricultural sector is at a critical crossroads in the EU, facing multiple, interlinked challenges globally that threaten its future viability. Climate change manifests not only in altered weather patterns but also in extreme weather events that disrupt agricultural production, increasing the risk for farmers and agricultural enterprises (Fischer et al., 2020). Simultaneously, global population growth intensifies the demand for food, necessitating a transition towards more efficient and sustainable farming practices. Market demands evolve rapidly, with both consumers and regulatory bodies insisting on higher standards regarding environmental sustainability and ethical production.

Since Hungary and Poland joined to the EU, the Common Agricultural Policy (CAP) helped their agricultural sector. The success of this complex support system needs to be revised time by time. The first 20 years period in the EU gives a visible milestone for us to research. Also, we need to see that the significance of measuring financial performance in conjunction with sustainability metrics have become apparent. The Farm Accountancy Data Network (FADN) in the EU performs data collection for decades, but has not collected regularly sustainability related data up till now. This means a serious gap in the available data and need to address retrospectively with research. This is one of the goals of the authors. As of 2025, the Farm Sustainability Data Network (FSDN) is set to replace the FADN (European Commission, 2024). This study aims to analyze the dual dimensions of agricultural performance by measurable financial health alongside sustainability efforts. Covering 10 years from the 2004 to 2024 period, we provide an overview on a larger, comprehensive work, addressing gaps in current literature. Through this approach, the paper attempts to equip readers with the necessary tools to improve their understanding in a rapidly changing market that requires economic and ecological improvements.

2 Theoretical Background

Historically, agricultural enterprises had often been driven by a desire for short-term profits, ignoring the long-term implications of unsustainable practices on environmental and social frameworks (Hawkes et al., 2021). Recently, however, a paradigm shift is occurring. Stakeholders, including consumers, investors, and

policymakers, increasingly recognize that integrating sustainability with financial performance is essential for the industry's future (Barbier, 2019). The Environmental, Social and Governance (ESG) framework has emerged as an essential tool in aligning these interests, enabling systematic assessment and enhancement of sustainability practices across the sector (Eccles et al., 2021). Indicators such as Sustainable Return on Equity (SROE) and Sustainable Profitability increasingly serve as benchmarks for evaluating the performance of agricultural business associations or partnerships not only on financial grounds but also concerning their social impact and environmental stewardship (Lehmann et al., 2021).

Recent research highlights the importance of technological advancements in achieving goals that are integrating both financial and sustainability terms. The adoption of Artificial Intelligence (AI) and Machine Learning (ML) facilitates precise data-driven decision-making, optimally balancing financial performance and sustainability (Zhang et al., 2023). For instance, precision agriculture—using IoT devices and satellite imagery—enables farmers to optimize resource usage, leading to reduced waste and enhanced crop yields. In the EU, initiatives such as the EU Farm to Fork Strategy advocate for the adoption of green technologies, providing practical frameworks for integrating sustainability into agricultural practices, as evidenced in various member states.

We can see significant actions under the CAP Strategic Plans and discussions on Member States level about the implementation of agri-environmental and sustainability measures. This demonstrates how such practices can simultaneously improve environmental sustainability and agricultural efficiency (Kádár et al., 2021).

3 Methodology

This study employs a mixed-methods approach, strategically blending quantitative and qualitative methodologies to achieve a comprehensive outcome. The analysis was based on EUROSTAT, the European FADN and the Crefoport, focusing on financial performance indicators. Data also arrive from publicly accessible financial statements and EU reports, ensuring a broad representation across different agricultural sectors.

In parallel, qualitative insights was gathered through interviews with agricultural researchers from the Hungarian Institute of Agricultural Economics and practitioners. The aim was to explore their perceptions regarding the challenges and opportunities associated with implementing sustainable practices in their enterprises. This qualitative phase prepares nuanced understanding of the contextual factors influencing the integration of sustainability within the financial framework. These results are used as guiding lines, and will be presented in a later stage.

The data analysis encompassed statistical evaluations. The thematic analysis employed to interpret qualitative data, pinpointing concerns expressed by practitioners regarding the availability of data on sustainability. This mixed-methods approach yields insights that bridge the gap between theoretical frameworks and practical applications in the agricultural sector.

4 Results

In this study, we utilized comprehensive databases, including Crefoport, Eurostat, and the FADN, to assess the agricultural sectors of Hungary and Poland.

Our findings indicate that the agricultural industry in the EU27 has generated significant improvements, such as in the Gross Value Added (GVA). Notably, the financial results of the agricultural sector in both Hungary and Poland have increased since their accession to the EU.

Table 1: Production value at basic price, GVA at basic (million euro).

	2005	2013	2023
Hungary	1 800,38	2 895,57	3 768,01
Poland	5 159,23	9 385,50	12 673,06
EU27	126 396,44	162 921,89	218 006,71

Source: Eurostat

However, significant differences exist in the various financial measures between the two countries, in which Poland performs better. It is crucial to note that the data utilized are usually aggregated, which may bias the results by not accounting for variations in operational structures and income levels across different types of farms.

The analysis also examined the level of engagement with sustainable initiatives, which proved more challenging to compare. Unfortunately, the FADN does not currently provide historical data, prompting us to supplement our analysis with financial reports from selected companies based on their geographical location.

In Hungary, the focus was on business associations and partnerships, whereas in Poland, data were compiled from a broader spectrum of company types, including individual entrepreneurs.

Our findings reveal that agricultural business associations or partnerships started to actively incorporate ESG metrics into their strategies. This demonstrates significantly higher SROE and overall profitability. Specifically, associations that successfully leveraged EU funding for sustainable initiatives—such as renewable energy adoption and organic farming practices—reported an average profitability increase of 15% over the past decade (European Commission, 2022). The EU's CAP plays a pivotal role in incentivizing sustainable practices, resulting in observable financial gains for those participating in these initiatives.

Furthermore, the integration of AI and Machine Learning (ML) technologies is revolutionizing farming practices globally. These advancements enhance irrigation schedules and fertilization techniques using real-time data, contributing to a 20-25% increase in efficiency, a 15-20% boost in yields, and a 25-30% reduction in operational costs due to more intelligent investment strategies and decreased reliance on manual interventions (Padhiary et al., 2024). The use of predictive analytics and IoT sensors has effectively mitigated the overuse of water and fertilizers, resulting in substantial cost savings. Additionally, drone technology for crop monitoring has enabled farmers to reduce pesticide utilization by 30%, illustrating how technological advancements can enhance productivity while protecting environmental resources (Wolfert et al., 2017).

During data analysis, both financial and sustainability dimensions were considered. This means quantitative evaluation of financial performance and qualitative sustainability impacts, such as reductions in carbon footprint and improvements in biodiversity.

The results of our dual measurement approach can be effectively applied not only in Hungary and Poland but across all EU Member States as well. To further enhance the integration of Environmental, Social, and Governance (ESG) metrics into agricultural performance, we make the following recommendations:

- A comprehensive reporting framework that extend beyond basic ESG metrics should be developed. The FSDN will facilitate more consistent and relevant data reporting.
- Encouraging partnerships between research institutions and agricultural entrepreneurs is essential for collecting data on equitable terms. Also, additional ESG-linked loan products should be developed that offer favorable terms to businesses adopting sustainable practices.
- To verify the benefits of ESG initiatives, further empirical research is necessary to quantify the impacts of these initiatives on both financial metrics and agricultural output.

By implementing these strategies, agricultural sectors across the EU can enhance their sustainability practices, drive innovation, and improve overall performance in alignment with broader EU sustainability targets.

5 Discussion

Integrating sustainability metrics with financial data yields numerous benefits for consumers, companies, and society at large. For consumers, it fosters transparency and allows for informed purchasing decisions, leading to ethical consumerism. Companies benefit by enhancing their reputation, attracting sustainability-focused investments, and reducing operational costs through improved efficiencies. Societally, integrating these metrics promotes responsible stewardship of natural resources and aids in tackling climate change, ultimately leading to healthier communities.

The results underscore the importance of integrating sustainability metrics with financial data as a means to cultivate a competitive edge in the agricultural sector. The interplay between technological advancements and sustainable practices emerges as a critical factor enhancing this competitiveness. Agricultural

entrepreneurs adopting a comprehensive framework, including both financial and sustainability benchmarks, are positioned to navigate market fluctuations and increasingly stringent regulatory requirements effectively.

Future research should explore the impact of specific sustainable technologies on agricultural productivity across different climates and regions. Additionally, examining consumer behavior towards sustainable agricultural products can provide insights into market dynamics. Questions related to the data availability is always the core to understand trends. The structure of data collection and the willingness from the stakeholders to share stays a major question. Data protection, dissemination of best practices and keeping technological secrets are key. Investigating the role of government policies in incentivizing sustainability within agriculture can also yield valuable information for stakeholders.

6 Conclusions

This study affirms that integrating measurable financial and sustainability data is essential for assessing the competitiveness of agricultural entrepreneurs in Hungary and in Poland. The shift from FADN to FSDN bears opportunities, though it also means sustainability approach, such as the ESG indicator was not collected in a public form. The effectiveness of the data collection has a barrier, though the Member State level research institutions establishing systems. The common approach should be a multi/mixed and the identification of best practices should be supported in EU level, for example by the EIP- and the CAP Network. By employing a mixed-methods approach, the research not only quantifies the financial impacts of sustainability initiatives but also highlights the important role of technology, particularly AI, in fostering competitiveness.

Various stakeholders play essential roles in ensuring positive outcomes. EU Institutions can enhance effectiveness by providing comprehensive guidelines and funding opportunities that promote sustainable practices. Countries can implement supportive policies that prioritize technological investments and sustainability education among farmers. Research institutions and the scientific community should prioritize research on innovative sustainable practices and technologies, providing knowledge and resources that can assist farmers in making informed decisions.

Future research should explore the longitudinal impacts of these metrics beyond the 2024 timeframe, encapsulating the evolving dynamics of the agricultural landscape. The shift from FADN to FSDN is welcomed. For Eurostat, it would be beneficial to collect data on sustainability metrics too, linked to specific agricultural practices, the environmental impact of production methods, and consumer purchasing behaviors regarding sustainable agricultural products. This data would not only facilitate a comprehensive understanding of agricultural sustainability in the EU but also inform policymakers in structuring incentives effectively.

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Macroeconomic Adjustments Under the Pitfalls of Quantitative Easing in the EU: Balancing Economic Growth and Inflation Across Monetary Regimes

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Institutional governance, along with economic development, plays a pivotal role in ensuring the effective transmission of quantitative easing (QE). This research aims to evaluate the efficiency of QE in stimulating gross domestic product (GDP) while simultaneously considering the impact on prices in the EU from a trade-off perspective over the 2014Q1-2023Q1 time horizon. The research is based on macro-panel data differentiating EU countries from the angle of monetary autonomy: EZ members (Austria, Belgium, France, Germany, Netherlands, Italy, and Spain) and emerging monetary autonomous EU economies (Czech, Hungary, Poland, and Romania). Empirical findings are based on the framework of non-stationary, heterogeneous, dynamic panels using a Pooled Mean Group (PMG) estimator to test whether QE's impact on GDP is strong enough to elevate prices. Our findings suggest that monetary convergence guaranteed EZ members stable economic conditions through adjustment and discipline. In contrast, the monetary flexibility of autonomous countries resulted in higher prices which subsequently hindered economic growth.

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1 Introduction

European integration led to trade liberalization, which was characterized by capital and monetary integration, culminating in the establishment of the European Central Bank (ECB). The underlying principles of this process catalyzed higher development, particularly for lower-income and Central and Eastern European (CEE) countries. This transformation entailed a shift from their previous economic systems to institutional democratization, leading to increased capital investment. The objective was establishing an inclusive framework of robust institutions that would foster economic stability and growth (Horvath & Voslarova, 2016; Blanchard et al., 2016). Despite the moderate success of integration, institutional divergences persisted at the EU level. In monetary terms, one group of countries retained their monetary autonomy, while others adopted fixed exchange rates and a single currency. This divergence had significant implications for monetary policy responses during crisis conditions among EU countries. Since the EU is a heterogeneous union, the lack of fiscal consolidation deepens policy coordination challenges. Additionally, a monetary union like the EZ leads to asymmetrical policy problems, particularly between the core and peripheral countries (Beker Pucar & Glavaški, 2021; Glavaški et al., 2023). The objective of this research is to highlight the trade-off associated with economic expansion and inflation through the lens of institutional governance of quantitative easing (QE) policy and adjustments across different monetary regimes.

This paper is structured as follows: after the introduction section, the following part of the paper presents a literature overview, while the third part of the paper explains methodological framework through the panel ARDL model (PMG and MG estimators). The fourth part of the paper presents research results while fifth discusses empirical findings concerning relevant issues.

2 Literature review

There is a rich literature that examines the dynamics between GDP and inflation from a trade-off perspective. The conventional approach was enlightened by the Philips curve, which established an inverse relationship between inflation and unemployment (Philips, 1958). Including QE in the analysis further complicates

dynamics, as unconventional monetary policy impacts both macroeconomic phenomena. The institutional framework remains crucial in shaping the outcomes of this trade-off, as controlling excessive expansion is essential for avoiding elevated prices. As suggested by Bernanke (2020), monetary decisions play a pivotal role in maintaining economic stability. Disciplined policy guidance helps prevent the occurrence of increased prices that adversely impact the economic outlook. In their study, Stojkov et al. (2024), suggest that QE policy in the EU increased inflation more than it depreciated currency resulting in real exchange rate appreciation. Some research papers (Christiano et al., 2005) imply that inflation-targeting policy can cause trade-off but the effects are negligible. Ferdinandusse et al., (2020), analyzed inflationary QE effects across different economic regimes confirming that lowering long-term interest rates increases prices. Conversely, QE plays a pivotal role in influencing GDP through asset prices, thereby triggering the wealth effect and stimulating consumption. Additionally, the QE policy will foster the demand for long-term bonds, leading to their increased prices and reduced returns. This phenomenon can, in turn, increase the consumption of asset holders, ultimately resulting in a boost in production. Furthermore, QE can help reduce economic uncertainty, thereby fostering a stable macroeconomic environment. This, in turn, can eventually lead to an increase in aggregate consumption (Hohberger et al., 2019; Hesse et al., 2018).

3 Methodology

Investigating the ramifications of QE policy on economic growth necessitates considering its expansionary effects on inflation. This is particularly important, as elevated prices resulting from increased aggregate consumption may hinder economic growth and potentially negate initial positive effects. To address this, we employ two distinct panel ARDL models, incorporating three key variables of interest: central bank's balance sheet assets (measured as a logarithmic function of central bank's assets (*lnqe*)); nominal gross domestic product (*ngdp*) and harmonized consumer price index (measured as price rate instead of index (*dhcpi*)). To avoid inflationary pressures and maintain positive economic outcomes, a robust institutional framework is essential, complemented by developed capital markets. An effective institutional design should provide transparent policy guidance, optimize economic objectives, and swiftly adapt to economic shocks. To differentiate

monetary regimes, and account for variations in monetary adjustment process to shocks, the sample is divided into two groups of countries. EZ members (Austria, Belgium, France, Germany, Netherlands, Italy, and Spain) and emerging monetary autonomous EU economies (Czech, Hungary, Poland, and Romania).

To shed light on the trade-off between GDP and inflation induced by QE policy, as well as differentiate adjustment mechanisms between two institutional and monetary frameworks, the authors use techniques based on non-stationary heterogeneous dynamic panels (Pesaran & Smith 1995). Consequently, since the time dimension in the sample is T=37 for both models in 11 EU economies (N=11), heterogeneous, non-stationary panels with cross-sectional dependence were utilized. Techniques introduced by Pesaran et al., (1999), offer estimation of dynamic panels where parameters are heterogeneous across the group: the Mean-Group (MG) and Pooled Mean-Group (PMG) estimator. PMG estimator is based on pooling and averaging coefficients resulting in one homogeneous long-run relationship along with short-run heterogeneous coefficients. MG estimator provides heterogeneous long-run relationships for each country in the sample but also heterogeneous short-run coefficients. Both estimators include the error-correction term (ECT) which explains adjustment dynamics to long-run equilibrium relationship for each country. Hausman specification test (Hausman, 1978) provides a decision on which model is more efficient in distinguishing if the long-run restrictions are true in the PMG model. For the null hypothesis, the homogeneous long-run relationship is true, PMG is more efficient and vice versa. The baseline model can be determined as:

$$\Delta y_{it} = \phi_i(y_{it-1} - \theta_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{it-1} + \sum_{j=0}^{q-1} \delta_{ij} \Delta X_{it-j} + \mu_i + u_{it}$$

where the cross-section units are represented by i = 1, 2, . . . , N; the number of periods t = 1, 2, . . . , T; X_{it} is a k ×1 vector of explanatory variables; ϕ_i is error-correction parameter, which presents adjustment mechanism toward long-run equilibrium relationship for each monetary autonomous and nonautonomous EU economy, error-correction parameter is expected to be negative under the assumption that long-run relationship exists and variables converge to long-run equilibrium, in contrast, $\phi_i = 0$ means that there is no long-run equilibrium; θ_i is long-run equilibrium relationship between variables; λ_{ij} is coefficient of lagged dependent

variable, δ_{ij} is short-run coefficient for each panel unit (EU economy), μ_i represents individual effects and u_{it} stochastic disturbance term. In this research, nominal gross domestic product (*ngdp*) represents the dependent variable investigated in relation to the impact of central bank balance sheet expansion policy (*lnqe*). Thus, our specification is:

$$\Delta ngdp_{it} = \phi_i(ngdp_{it-1} - \theta_i lnqe_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}\, \Delta ngdp_{it-1} + \sum_{j=0}^{q-1} \delta_{ij}\, \Delta lnqe_{it-j} + u_i + u_{it}$$

In our second model, testing the trade-off perspective, the dependent variable is the harmonized consumer price index (*dhcpi*) while the independent variable is the central bank's balance sheet expansion policy (*lnqe*). We can estimate the following model:

$$\Delta hcpi_{it} = \phi_i(dhcpi_{it-1} - \theta_i lnqe_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}\, \Delta dhcpi_{it-1} + \sum_{j=0}^{q-1} \delta_{ij}\, \Delta lnqe_{it-j} + u_i + u_{it}$$

4 Results

In order to obtain final estimation results regarding short-run and long-run relationships certain empirical steps were performed. First, testing cross-sectional dependence (CSD) with the null hypothesis of cross-sectional independence among highly integrated EU economies is expected to be rejected (Pesaran, 2007). Second, the Panel unit root test is investigated (PURT) with Pesaran's second-generation stationarity test accounting for cross-sectional dependency. Third, the Westerlund cointegration test is performed, with the null hypothesis suggesting the absence of a long-run cointegrated relationship between variables (Persyn & Westerlund, 2008). Finally, choosing which model is more efficient between MG and PMG estimators of the panel ARDL model is concluded with the Hausman test. In the following section, results of the panel ARDL model are presented.

Table 1 presents baseline estimation results using MG and PMG estimators, analyzing the positive dynamics between QE and GDP. The results indicate homogeneous coefficients, assuming a consistent long-run relationship across all 11 EU countries.

Table 1: PMG and MG estimator results for 11 European economies in the period 2014Q1-2023Q1 (homogeneous coefficients)[1]

Sample: 11 EU economies; period 2014Q1-2023Q1						
Dependent variable: *ngdp*	Long-run equilibrium (θ)		Error-correction (Φ_i)		*Δlnqe*	
	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
MG	68540.63	0.000	-.2409987	0.000	-43312.87	0.000
PMG	28035.99	0.000	-.0934792	0.031	-21398.99	0.000
Hausman test statistic	4.15	0.2454				

Source: Author's estimations.

To account for institutional heterogeneity and country-specific dynamics, Table 2 reports heterogeneous PMG coefficient estimates for each of the 11 economies. The table enables insights into analysis of both short- and long-run monetary adjustments of GDP to QE at the individual country level.

Table 2: PMG estimator results for 11 European economies in the period 2014Q1-2023Q1 (heterogeneous coefficients)

Sample: 11 EU economies; period 2014Q1-2023Q1 Dependent variable: *ngdp*				
PMG Estimator	Error-correction (Φ_i)		*Δlnqe*	
EZ members	Coeff.	*p*-value	Coeff.	*p*-value
Austria	-.0264289	0.122	-4982.236	0.465
Germany	-.043228	0.549	-42148.15	0.387
France	-.456345	0.001	-94176.56	0.035
Belgium	-.0421972	0.085	-4954.867	0.571
Netherlands	-.139381	0.008	-21890.18	0.046
Italy	-.2701313	0.007	-50406.74	0.146
Spain	-.2644414	0.007	-49082.01	0.118
Monetary autonomous EU countries				
Czech	.0321324	0.289	-15206.39	0.843
Poland	.0434941	0.391	-28443.43	0.013
Hungary	-.0534862	0.075	-6908.552	0.059
Romania	.0379069	0.518	2814.386	0.689

Source: Author's estimations.

[1] Pre-estimation procedure can be additionally requested.

To investigate the inflationary consequences of QE, Table 3 summarizes the homogeneous results of the MG and PMG estimators where we analyze the dynamics between QE and inflation. The table showcases QE's effect on prices, controlling for convergence speed and long-run dynamics.

Table 3: PMG and MG estimator results for 11 European economies in the period 2014Q1-2023Q1 (homogeneous coefficients)

Sample: 11 EU economies; period 2014Q1-2023Q1						
Dependent variable: *dhcpi*	Long-run equilibrium (θ)		Error-correction (Φ_i)		*Δlnqe*	
MG	Coef.	*p*-value	Coef.	*p*-value	Coef.	*p*-value
	2.779744	0.000	-.8582944	0.000	-2.086216	0.000
PMG	1.493432	0.000	-.790868	0.000	-1.380948	0.092
Hausman test statistic	3.59	0.0583				

Source: Author's estimations.

Finally, Table 4 offers a country-level breakdown of QE's influence on inflation, allowing us to contrast the adjustment dynamics and inflationary sensitivity between EZ and monetary autonomous EU members. The level of divergences is essential for identifying vulnerabilities related to institutional governance.

Table 4: PMG estimator results for 11 European economies in the period 2014Q1-2023Q1 (heterogeneous coefficients)

Sample: 11 EU economies; period 2014Q1-2023Q1 Dependent variable: *dhcpi*				
PMG Estimator	Error-correction (Φ_i)		*Δlnqe*	
EZ members	Coeff.	*p*-value	Coeff.	*p*-value
Austria	-1.060758	0.000	-3.821488	0.166
Germany	-.7736291	0.000	-1.1032	0.692
France	-.7589665	0.000	-1.12916	0.492
Belgium	-1.088509	0.000	-.7988119	0.821
Netherlands	-.5617581	0.002	6.671198	0.063
Italy	-1.676413	0.000	-8.220577	0.031
Spain	-1.505097	0.000	2.042845	0.554
Monetary autonomous EU countries				
Czech	-.5291965	0.021	-1.715685	0.739
Poland	-.2480151	0.054	-2.249097	0.486
Hungary	-.1246379	0.238	-2.050155	0.587
Romania	-.372567	0.007	-2.816295	0.255

Source: Author's estimations.

5 Discussion

Fundamentally, the primary objective of QE policy is to prevent recessionary pressures through indirect monetary channels. However, this mechanism can be hindered from a trade-off perspective if asset prices become elevated enough to slow down economic growth by increasing inflation. As presented in Table 1, the dynamics between GDP and QE are analyzed for the 11 EU economies during the 2014Q1-2023Q1 time horizon. Panel ARDL analysis in the short-run reveals a statistically significant inverse relationship between QE and GDP for 11 EU economies. This corresponds to the time lag effects of monetary phenomena, as policy effects require time to adjust for their long-run effects. To confirm the presence of lagged effects in the short run, the analysis shifts to the long-run, where it is observed that strong and significant positive effects are present between the variables. Both models confirm the initial policy intention of affecting real economic variables in crisis conditions. Hausman specification analysis presents results with a *p*-value of 0.24, indicating that the null hypothesis cannot be rejected. Consequently, the efficient estimator is PMG, while the ECT is significant and negative (-0.09), implying that GDP adjusts at a 9% speed of adjustment each quarter.

Analyzing Table 2, heterogeneous coefficients are presented for each economy in the sample, illustrating the effects of QE on GDP. Adjustment to the long-run relationship is detected in six economies, while short-run coefficients remain significant for two economies. Regarding the EZ members, adjustment to the long-run relationship is confirmed in general for all members except for Germany and Austria. As both countries are core EZ states, their lower need for monetary adjustment is evident in response to external shocks. Germany plays a pivotal role in shaping EZ economic policy, while Austria's close ties, similar institutional design, and reduced exposure to external capital flows diminish the necessity for adjustment. In contrast, for monetary autonomous EU countries, only Hungary exhibits statistically significant adjustment to the long-run relationship (10%). This suggests that coordinated economic adjustment of GDP expansion to the effects of QE is generally absent or low for monetary autonomous EU countries, potentially increasing risks of spillover to elevated prices and resulting in trade-off that hinder growth. In the short-run, the dynamics of EZ members hold significant implications for France and the Netherlands, which are heavily reliant on a robust banking sector

that facilitates prompt monetary transmission. Conversely, Poland stands alone as the only autonomous country with substantial short-run dynamics, primarily driven by its reliance on small and medium-sized enterprises in their aggregate consumption structure. Similar findings regarding GDP and QE dynamics are confirmed by Baumeister & Benati (2013), Weale & Wieladek (2016), and Chen et al. (2012).

Analysis of the QE and inflation dynamics for the 11 EU economies are presented in Table 3. The short-run indicates an inverse relationship for both models, while PMG coefficients are not statistically significant. In the long-run, confirmation of inflationary presence is confirmed since both models suggest high, significant, and positive coefficients. ECT is slightly higher for the MG model while in both cases statistically significant, suggesting an adjustment to the long-run relationship toward elevated prices is present.

As presented in Table 4, heterogeneous coefficients are exhibited for 11 EU economies in relation to QE and inflation dynamics. In the short-run, there is no evidence of significant QE influence on prices for all the economies in the sample (with the exception of Italy). This suggests that prices require a longer time period to adjust to increased aggregate consumption and GDP expansion. Shifting the focus to the long-run dynamics, it can be observed the significance of adjustment to monetary shocks for all EU members, exemplifying high levels of adjustment (Germany, France, and the Netherlands) or over-adjustment to elevated prices (Austria, Belgium, Italy, and Spain). Conversely, only Czech and Romania exhibit significant adjustment to the price dynamics of the autonomous countries. However, adjustment coefficients are significantly lower than those of EZ members. This can be attributed to the presence of a trade-off between GDP and inflation, as the institutional framework is less robust. Research conducted by Lenza et al., 2010 and Kapetanios et al., 2012 indicates a positive relation between asset purchases and increased prices. Flexibility in monetary policy allows for overheating through GDP expansion, which results in inflation hindering economic growth. In contrast, institutional governance in the EZ states adopts a more disciplined approach to controlling GDP expansion, thereby ensuring stable economic growth without excessive inflationary pressures.

6 Conclusions

This paper explores dynamics between QE, GDP, and inflation along with differences in institutional governance and adjustment mechanisms across monetary regimes in the EU. Conventional policy limitations required the introduction of unconventional monetary measures however, disciplined and robust institutional guidance is imperative for mitigating potential negative repercussions. Even with the common factor of European integrations for all countries, limitations in GDP adjustment leading to overexpansion reveal persistent divergences in policy reactions between institutional frameworks as well as monetary regimes.

The estimated, heterogeneous, dynamic, macro-panel of 11 EU economies in the period 2014Q1-2023Q1 helps us in analyzing short-run and long-run dynamics among the two groups of countries differentiated by monetary autonomy, level of development as well as institutional framework. The primary finding indicates that QE policy exerts a de facto significant role in mitigating crisis conditions. However, the discipline of institutional decisions determines whether the policy is implemented in a manner that avoids elevated prices affecting growth. For EZ members, the adoption of a policy framework provided support for economic activity while simultaneously adjusting for excessive expansion to prevent inflationary pressures. Conversely, autonomous countries granted flexibility in policy guidance, resulting in a trade-off between inflationary pressures and economic growth.

These findings underscore the paramount importance of further institutional integration at the EU level, which will provide enhanced coordination among member states in monetary policy responses. By reducing divergences among countries, we can enhance the resilience of economic reaction to external shocks and foster sustained economic growth.

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Capacity Building, Management and Sustainability Values

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Reality context, European Union policy priorities, building people wellbeing and system resilience, research and innovation promotion, - they all demand quality management and its sustainability within actual changes. The sustainability concept puts EU citizen's health in focus: the health is a value and it is the driver of productivity. The healthcare system is the central part within the country's resilience: Only healthy people enable productivity and added value. The added value is the key driver of competition also within the Draghi's Report, prepared for European Commission and has been used for existing strategy correction and for future financial perspective 2028-2034 preparation. The paper exposes importance of education and training of three different dimension of capacities (individual, institutional and system) within the real context of health policy. Management is to be skilled in conceptual managing action and to be involved in methodology preparation and removing its barriers.

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1 Introduction

Connections between education, entrepreneurship and policy conceptualisation and implementation explore learning issues, introduce key themes while focusing on the deeper context behind continuous skill-building in a world that is changing at a dizzying speed. The rise of AI and the urgent need to tackle the sustainability crisis, require flexibility, interdisciplinary collaboration, key themes to take into account, systematic rethinking and system approach. We are involved in advancing sustainability, conceptualising and implementing policies that drive growth, protect consumers, and help businesses thrive in a fast-changing digital world. While EU multilevel system of governance engages actors horizontally and vertically even outside the territory of the Member States, there is a need of new enforcement for management competences and skills are needed for working in public and private sector. That is why barriers are found in capacity building and methodological obstacles that management should be aware and is to take care about managerial competences and skills.

The paper takes into account actual EU findings and recommendations, as the modern management is in the complex and system transformation. That is why it is not only to empower competences of an individual, but at the same time institutional and system capacities. There is a need to empower the methodology instruments as the methodology is an important management instrument in its way from planning to implementing business activities. It is important that management is capable to follow up the changes in light of cross-cutting challenges, use of digital technologies and influence of climate changes to health and competitiveness.

Recent findings from disciplines, like socio-legal research, behavioural studies and law & economics, have been enriching common understanding on an important interaction between law & economics and behaviour. Sustainability values are not the same as neoliberalism values. Issues have to be followed up, to debate, to come together and to be applied to national context, especially in case of small country. From policy economic point of view, also managerial and organisational, important issues are: the rule of law, the effectiveness of actions, individual, institutional and system effectiveness of their engagement, the challenges that enforce needs and to meet supply and demand side of services within the country's framework. The key driver of them are capacities, prepared and agreed methodological instruments to

act (e.g. business model has to change in sustainable business model) in the context of the UN Sustainable Development goals.

At the same time these are also the drivers of competitiveness (as they are enablers for productivity). Big task is to put resilient system in place: »As first, conceptual, as second knowledge failures, research and information challenges as it is to address social and environmental drivers, willingness and ability to deal with decision making frameworks. Thirdly, implementation failures as they are governance challenges, such as how governments and institutions delay recognition and responses to threats, to pool common resources and time lag between action and effect« (Whitmee, S. et alt., 2015. pp. 1973). Academic work over the last years has attempted to conceptualize resilience as it pertains to systems. But what do we know in terms of its practical application, it is not enough, especially in times of fatal global changes and economic war.

State shift is needed as there have to be large, lasting changes in the structure and function of social-ecological systems, with substantial impacts on the services and products. For a small country resilience is very important. It does mean the capacity of any entity – an individual, a community, an organisation – to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow. »Today there is a growing awareness that humanity's historical patterns of development cannot be a guide for the future« (Whitmee, pp.1976).

Resilience thinking is one of possible decision making under uncertainty. Resilience thinking focuses on identifying and managing critical thresholds for system performance, »maintaining capacity to adapt surprises by conserving key processes« (pp. 2013). »Resilience thinking can be combined with decision theory threshold approaches (systematically organised processes) scenario planning (supported with data) to guide management« (pp. 2013).

2 Theoretical Background / Literature Review

The EU is committed to achieving the 17 UN Sustainable Development Goals. (https://www.un.org/sustainabledevelopment/health/, 2 December 2023). The European Green Deal aims to develop a sustainable, climate-neutral and ecologically aware economy by 2050. The EU Social Agenda (and the revised Agenda in 2008

https://ec.europa.eu/social/main.jsp?langId=en&catId=89&furtherEvents=yes&newsId=376) introduced a knowledge-based society in 2000. The EU strives for solid development, for the cohesion of the member states: this is what cohesion policy measures serve in the last two financial perspectives (2014-2020 and 2021-2027 periods). Its most important substantive and financial cohesion, existence and development (https://ec.europa.eu/regional_policy/policy/what/investment-policy_en).

An essential component of cohesion legislation – governance and management should be aware - is a joint commitment to establish systemic shared management. The situation with the individual capacities, especially the administrative competence of the managing authority, is constantly monitored in the EU. The new findings come in the documents 'Study on Roadmaps for Administrative Capacity Building' and 'Organizational models of program authorities managing EU cohesion policy' (https://ec.europa.eu/regional_policy/policy/how/improving-investment/studies_en). Slovenia, like other countries, faces the challenges of sustainable action; but since it is small, even greater vulnerability is to be expected. The European semester, which intensively analyses the situation, watches over the quality of action and the readiness of social security systems, repeatedly highlights the need for reforms and greater intensity of changes for Slovenia (https://commission.europa.eu/system/files/2022-05/2022-european-semester-csr-slovenia_en.pdf).

The European Union (EU) agreed UN SDG, EU also declared Social Pillar in 2016 with its 20 social rights. EU has long positioned itself as a global advocate for human rights, embedding this commitment within its external action policies, as a part of EU Values. The Treaty on European Union explicitly states that the Union's actions on the international stage shall be guided by the principles that inspired its own creation, including democracy, the rule of law, and the universality and indivisibility of human rights and fundamental freedoms.

In 2023, the European Commission (EC) adopted cross-cutting standards for the disclosure of Environmental, Social and Governance (ESG) information. Reporting issues as pillars of the European Sustainability Reporting Standards are numerous: Climate change, Pollution, Water and marine resources, Biodiversity and ecosystems, Resource use and circular economy, Own workforce, Workers in the

value chain, affected communities, Consumers and end-users, Business conduct, etc. The sustainability reporting revolution begins, however the further guidance is still expected to address its implementation challenges. These are methodological barriers: among them the definition and the content of material sustainability/ESG information, to how to collect the required ESG information.

Management has to manage problematics and to address the changes in corporate culture, the emergence of a sustainability governance. There must be an enhancement of risk and the contribution of sectorial analysis. It can be said that the healthcare area in EU has been empowering in last years and ecosystems with academic support drive the transition from a purely share-holder oriented perception of value to a stakeholder and sustainability value vision with a lot of methodologic work on different instruments (frameworks, models, data). That is why capacity building is important and to be aware of important of methodology as a managerial instrument. The context of managerial action is not only sustainable transition, but also the governance and managerial focus is to be on the following four areas of particular interest: 1 Enforcement (rule of law, competence issue, legislative design of enforcement, inclusion of empirical findings to enforce practice, etc.), 2 New Challenges (digital law, artificial intelligence, AI, data, sustainable transition), 3 External dimension (impact of enforcement actions for resilience and recovery, especially of different systems – as public health system to be in place) and 4 Interdisciplinary aspects (sociology, cybersecurity, political science, law & economics, behavioural studies, etc.).

OECD, European Semester, WHO and other institutions are monitoring and analysing how well are covered with action the four above mentioned areas. EC Directorates Generals prepare recommendations and methodologies to use in practical implementation of action. However, every single country has to act in the specific context. OECD, as example, exposed several times that »Healthcare systems need to better respond to patients' needs: There is an urgent need to adapt healthcare systems to better meet the needs of the growing number of people » (the findings of the first international OECD 2025 survey of patients living with chronic health conditions). While policy-makers conceptualize performance their implementation activities need policy managerial capacities, institutions and systems to work well to overcome challenges and capture the perspective.

3 Methodology

The method used is explanatory-research. This method initially explains why the topic is important and then highlights important documents, the causes and consequences of action. Based on their content, it reveals the most important problems and challenges. The main challenge is to define, in the context of building individual, institutional and systemic capacities, what are the most important methodological obstacles or barriers while effectively managing resources when planning and implementing activities in the sustainability context while exposing some cases in the healthcare area.

The paper's goal is focused on determining a common set of issues relevant for management as business-makers, for being used for academia to prepare students with competences and skills to settle down conceptualisation frameworks and methodological instruments for organizational agency.

The development of this paper framework consisted of a literature review of existing policies, concepts and initiatives referring to managerial and good governance work in EU and sustainable development goals context. Paper is based on numerous papers of OECD, European Semester and Court of Audit of the Republic of Slovenia (www. rs-rs.si) – they all exposed delay in action to empower systems and resilience (https://www.consilium.europa.eu/sl/policies/european-semester/, 8.2.2025). The inventory of competences was done: entrepreneurial (EntreComp), digital (DigComp) and Green Competences. The European Union's GreenComp (Bianchi et al., 2022) served as a solid basis for mapping relevant competency areas as they describe the key competences needed to transform students and managers into sustainability thinkers and doers. In depth case of management in Slovenia was done (Maher, Management and efficiency, International Conference Globalisation Challenges, 2022). Then this paper's conceptual model was prepared to expose focus to capacity building, starting from OECD findings presented. Then methodological obstacles as instruments which are needed by management when implementing policies and measures, are exposed.

The paper exposes methodological barriers that management should overcome, as they are especially important in the sustainability context. EU documents expose four areas of methodological barriers: 1 conceptual (as first the agreement on

definition), 2 methodology (different methodologies, standards and indicators), 3 data (availability and quality), 4 political decisions (European Observatory, 2025 in Disse, HAL, 2024, str. 1). Developing the sustainability competences and skills is crucial to facilitating the transition to an economically viable, socially just and environmentally sound future. Emphasising managerial resilience competences and fostering their ability to adapt to change, will be managing transitions and can contribute significantly to the sustainability direction.

The paper should be up to 6 pages long, including references. Please do not paginate the paper. It should follow a scientific paper structure and comprise major sections: introduction, literature review or theoretical background, methods (if applicable), results (if applicable), discussion, and conclusions. Make sure that all parts of the paper follow the principles of scholarly writing.

4 Results

Management and four areas of methodological obstacles

For management methodological issues refer as important management tools to use them against challenges and limitations, when designing planned action and its implementation. «There is a list of proposed reforms, however the gap is still in between there are methodological obstacles« (OECD, pp. 25). Good and in time prepared methodology instruments as frameworks, models, standards, definitions, etc. impact the validity and reliability of results, and the specific components of an approach. Four areas and their instruments are: 1 conceptual (consensus on a single definition is important first), 2 methodological (standards and various uniform methodologies, indicators), 3 Data (availability and quality), 4 political decisions (European Observatory, 2025 and Disse, HAL, 2024, p. 1). (European Observatory, 2025 in Disse, HAL, 2024, str. 1).

There is a lot of discussion how to push student's and workers' creativity. However, it is first to put down also methodology and its theory not to lose time and activities to focus inside different area frameworks. Responsibility of everybody is important: Member states tasks were to indicate »why their prioritised challenges and/…/how their plans represent a comprehensive and adequate response« (OECD, pp. 8).

Definition and the concept

The glossary is to use as definitions are very important agreement and the starting point of any action. When the definitions are clear, they provide a foundational framework for organisational action. The definition is important for training and education in the sustainability context. That is why the EHMA study is good case (EHMA is European management agency) why it is important to elaborate the definition broader in its context because the action is needed in different dimensions. EHMA is showing its three methodological steps towards a definition of health management: from preliminary definition, then the concept was suggested and then final working definition was put down.

EHMA case of three parts of definition, and defined through its concept, serves as a perfect guidance to all. It has even significant implications for the way systems are structured, governed, and administered, particularly in the context of sustainability. It offers a conceptual foundation also for system resilience. »Policymakers can use this definition to establish clear guidelines for the integration of management practices that address social, environmental, digital and economic determinants« (pp. 4).

For preliminary definition health management encompasses the planning, organising, coordinating, and overseeing of resources, processes, and activities of health systems to achieve optimal health outcomes for individuals and populations. As second, it is important to suggest key concepts. Key words for key concept were: »Broader than 'healthcare management'—holistic—One Health—digital health—environmental health—intersectoral collaboration—multidisciplinary—different levels of governance—behavioural, social and economic determinants of health—governance structures« (Valiotis, 2025, pp. 3). Through the sustainability concept together with the definition, key words were used. From the third - working definition - it is obvious that »health management involves providing guidance and leadership to promote health at all levels. It adopts a holistic vision /…/spanning community, primary, secondary, and tertiary care—it extends beyond these settings to foster collaboration across related policy and societal domains /…/« (Valiotis, pp. 3).

EHMA's elaboration of definition was done with the scope that in such a way manager is aware to »engage with a wide array of stakeholders, including patients, caregivers, patient organisations, policy makers, regulators, public health experts, researchers, and industry representatives. Together, they work to create shared health goals and develop the organizational, societal, and technological foundations necessary for achieving sustainable health outcomes. Health management also emphasises the importance of effective governance structures that support co-design and co-production with communities and stakeholders« (Valiotis, pp. 3).

This definition can help health authorities create performance metrics that assess not only the clinical effectiveness of healthcare systems but also their equity and sustainability. These metrics can incentivise a reduction in environmental impact, increased accessibility of services, and greater interdisciplinary collaboration across sectors. This definition also supports governance structures that facilitate co-design and co-production models, where communities and other stakeholders actively participate in the decision-making process. The participatory approach ensures that health systems are more responsive to the needs of the population, leading to more equitable health outcomes when health managers play a key role in fostering governance models that support collaboration across sectors and ensure that the policies implemented are inclusive, just, and sustainable.

Methodological issues

OECD warns: »Whatever the content is (renovation of residential building, decarbonisation, investment in infrastructures and digitisation) there are methodology basics. Be aware and to build as first a good concept, approach and project design and performing cost estimates (OECD, pp. 37). Methodology is a key for system management. For example, for health system readiness five guiding principles are prescribed: data, system thinking, collaboration between communities, healthcare professionals etc., understanding the local context and iterative improvement (EHMA 2023 Health system readiness for innovation, pp. 5).

In EU frameworks became very important to focus action. After European Framework Quality of Management in 1992, for healthcare activities the European Social Quality Framework with six principles is proposed (https://www.esn-eu.org/news/towards-european-framework-quality-social-services). Pillars are

proposed, as: 1. Human Rights based 2. Person-centred 3. Outcomes-oriented 4. Safe 5. Community-based 6. Well-managed. The last one is the management pillar as it is important to organise, guide the action and formulate quality indicators that will help practitioners measure compliance with the standards.

Data availability and quality

The European Health Data Space (EHDS) is moving fast from its concept to reality; is not only legislation and theory but aim to enhance citizens´ primary use of data while promoting the ability to reuse data for the benefit of society as a whole. In ensures data privacy. Its effectiveness will depend on a number of factors, including social trust, digital proficiency, and connectivity throughout the EU, in addition to the ability of Member States to effectively implement the legal basis of the legislation created on a set of guidelines, infrastructure, while governance mechanisms are to facilitate the usage of AI and electronic health data. EHDS is about 1. Primary use = use of data for the delivery of healthcare (Improving patients' access to their health data and ensuring seamless exchanges for continuity of healthcare. 2. Requirements for electronic health record (EHR) systems and creating a single market for electronic health records systems, supporting both primary and secondary use. 3. Secondary use = use of data for research and public interest purposes as making data available for research, policy-making etc. in a safe and secure way (EC EHDS, pp. 12).

Its effectiveness will depend on a number of factors, including social trust, digital proficiency, and connectivity throughout the EU, in addition to the ability of Member States not only to effectively implement the legal basis of the legislation but of its capacities (individual, institutional and system). The webinar about EHDS implementation and governance (March 6, 2025), following Regulation EHDS, declared definitive timing for all needed specific activities, e.g. to connect service providers till 26 March 2027. There are already named digital health authorities by member states. The transition from eHealth network to new governance mechanisms should be finished in 2031. Policy making and regulatory activities that support public sector bodies or institutions is very active, and also higher education or teaching activities in health or care sectors have to improve delivery of information.

DigComp (The European Digital Competence Framework for Citizens) has become a reference for many digital competence initiatives and also EntreComp and European Framework for Digitally - Competent Educational Organisations – DigCompOrg. It was expected that all these methodological papers and instruments would be broadly studied and used for digital transformation. DigComp is important framework on the conceptual reference model with five dimensions (information and data literacy, communication and collaboration, digital content creation, safety, problem solving) also with new vocabulary.« For digital content creation – programming to plan and develop a sequence of understandable instructions for computing system to solve a given problem or perform a specific task« (DigComp, pp. 9). Not all, only some countries developed projects in which they support the professional development of their workers. Such examples are Carer+ project and Digital Competences for Teachers (OECD, 2022, Health Data Governance for the Digital Age, pp. 24-25). It was analysed that most organisations were late in finding »answers to following questions: How do enterprises manage the concept of digital competences compared to the traditional view of IT skills? How to design skilling actions of a set of competences, in particular, how digital competences contribute to develop skills? (OECD, pp. 50)".

Political decisions

EHDS area is a good case of fast-moving action following the political decision. EC also introduced for period 2021-20 new instruments as missions are to push the broader strategic and policy framework of action. »This requires not only a capacity to learn from these experiments and reflect this knowledge into existing or new initiatives (reflexivity), but also a high-level political commitment« (OECD, 2021). Mission-oriented innovation policies form a new system policy approach to address greatest societal challenges (OECD Science Technology and Industry Policy Papers, pp. 10).

These documents and instruments management has to take into account, following also EU recommendations, economic considerations, and SDG constraints. As competition policy is important it is also to invest in intangibles (as since 2014, it has been considered that investing in intangible assets brings greater profits as investing in tangible assets). However, this segment is very poorly monitored, and the commercialization of such services and products is not encouraged enough. It

ignores the fact that the value of the company is more than the value of physical capital and management of business processes; today, »in a knowledge-based society, the value of a company is the sum of physical capital plus human capital plus social capital + intangible assets« (Corrado, C., Haskel J., 2016).

Individual, institutional and system Capacity building

When we talk about capacities, it should be pointed out that we are actually talking about the dimensions of three types of capacities: individual, institutional and system capacities. It is about much more than individual learning and the acquisition of knowledge, it is actually also about transferring these skills to the capacity of systems and institutions.

Systemic and administrative capabilities are important for successful operation and project results, but the knock-on effect – strong systems and administration even more so. Therefore, it is essential to invest in management, to build adequate capacities for the management of EU funds between all levels of government and for the creation of strong investment strategies. Colloquially, the term 'institution' is used as a synonym for 'organization', which is not at all appropriate from a professional point of view and leads to many misunderstandings. In the EU, the term institution should also be understood as rules and not just an organization that operates according to rules. It is also necessary to understand the powers and responsibilities assigned to people with competencies at different hierarchical levels, including their actual implementation in practice.

Capacity building is needed as first for promoting not only managerial leadership, but also management to be efficient in its other four functions: planning, organisation and coordination, human resource management and control functions. Empowered management can function as a driver of change when promoting leadership in economies and decent work, transforming the public and private sectors, accelerating innovation and entrepreneurship, investing and closing different gaps. »Innovation is a collective process. It takes a very longtime and is highly uncertain« (Mazzucato pp. 7).

5 Discussion

OECD analysed that "countries have trained and professional personnel, but these human resources are not perceived or managed as representing also a strategic advantage" (OECD, 2020, p. 11). It is mostly managed within traditional hierarchical structures where talent management is not perceived strategically to achieve investment objectives. There is no understanding of human resources management. "This often leads to a lack of certain skills or a misallocation of skills, a lack of formalization of job profiles and roles, and poor anticipation of skills needs and workforce planning" (OECD, p. 11). However, there is a lot of desire for training and being educated and trained. It is important that "staff keep developments in legislation and regulation" (OECD, p. 11).

Strong institutions are important (together with good management) as there are double challenges in the strategic implementation of programs: in their strategic approach to program implementation and in the investment cycle, which affect the efficiency of spending. "Overall, there is room for increased capacity in strategic planning, prioritization, information and knowledge sharing, and performance measurement. There is scope for building stronger partnerships (OECD, p. 11). In the EU healthcare area there is a lot of action and of empowerment of institutions: Funded under EU4Health programmes, the Joint Actions JANE and CraNE worked on the establishment of cancer networks. Joint Action JANE conceptualised seven new Networks of Expertise while focusing on personalised prevention, survivorship, palliative care, technologies, hi-tech medical resources, complex & poor-prognosis cancers, adolescents and young adults with cancer. Joint action CraNE prepared the necessary preconditions for the creation of EU Networks of Comprehensive Cancer Centres (CCCs) and to develop an EU network to connect them. This institutional action continues under EU4Health as JANE-2 and EUnetCCC from November 2024 and addresses key EU health policy priorities.

The OECD points out that system capacities are in favour of a regulatory and legal framework (both at the national and European level). Although the principle of equality applies for all, there are inconsistent interpretations in the control, verification and audit procedures. OECD exposed that "public procurement laws are complex across countries and contribute to the creation of an administrative burden and high transaction costs. This can lead to implementation delays, financial

corrections, distrust in the system" (OECD, p. 11). OECD also highlights the problem of understaffing in the context of public procurement as a system obstacle: "although people may be understaffed and/or undertrained, more importantly, they often lack empowerment and incentives" (OECD, p. 11). Also the findings of audits by the Court of Audit of Slovenia are that "the strategies are inconsistent, they are not based on needs analysis, the operational plans that derive the strategies have not been made, the indicators of results have not been defined in advance, even the indicators that are already listed in the legislation have not been taken into account" (Efficiency of public institutions 2014-2018, poverty, self-sufficiency, etc., archive, www.rs-rs.si).

Regarding the healthcare, it is also a system problem that the health spending is considered catastrophic when it accounts for 20% or more of a household's spending capacity, as there is a risk of impoverishing because of health spending. That is why the Constitution rights (the Slovenian Constitution, art. 3) are the guiding principles of national healthcare services and because of them, the system must be put in place.

6 Conclusions

Paper showed that methodological instruments are to be well prepared to action as methodological problem or instruments not prepared in time for action can be serious barriers to act in time and in efficient way. For areas of barriers are to be exposed: 1 conceptual (consensus on a single definition is important), 2 methodological (standards and various uniform methodologies, indicators), 3 data (availability and quality), 4 political decisions.

This paper's key messages could be: For managerial action there must be built always a concept is for understanding and a framework to include most important drivers of competition and sustainability. Threats (economic, social, environmental and managerial) are to be taken into account to discuss clear what is required for urgent and transformative action as present generations are accountable for future ones.

The present systems of governance and management need more knowledge and capacities to adequate address threats and to improve the integration of economic, social and environmental policies for creation interdisciplinary knowledge.

The paper makes as main contributions to a methodological differentiation within the scope of 'sustainability practices of global interest' and 'sustainability practices into capacity building scope' from the managerial perception. The paper focuses to 4 methodological drivers. As capacity building is needed also to overcome methodological barriers, it is important not to jeopardise the creation of capacity and at the same time it is to enhance organizational managerial functions. This paper practical implications is to pay attention to the importance of aligning administrative and business expectations around sustainability, but in time to create a methodological framework that can be useful for fully embedding and identifying different gaps. It is important that student learn and discuss methodology instruments and their perception as they should be skilled in preparation and implementation of action.

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Integrating Mediation in the Corporate Culture as a Sustainable Practice

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This article examines the integration of mediation into corporate culture as a sustainable practice, emphasizing its capacity to transform conflict into a strategic asset that enhances organizational resilience, employee well-being, and long-term corporate sustainability. Drawing upon an extensive review of the literature from conflict resolution and sustainability studies, the article elucidates the mechanisms by which mediation contributes to a healthier work environment and fosters ethical and adaptive management practices. Mediation possesses all the essential characteristics of a sustainable practice, and its integration into corporate culture could contribute to enhancing business sustainability. Among these characteristics are cost reduction, increased stakeholder satisfaction, the achievement of lasting solutions, and the resolution of conflict situations.

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1 Introduction

In the contemporary, complex business landscape, organizations face the dual challenge of adapting to rapid changes while ensuring sustainable practices. A crucial factor in sustainable performance is the establishment of a resilient corporate culture, defined by shared values, beliefs, and behaviours that influence employee satisfaction, innovation, and operational efficacy.

Mediation serves as a valuable mechanism for conflict resolution, characterized by a voluntary process in which a neutral mediator facilitates dialogue between disputing parties to achieve mutually acceptable outcomes. The mediator, trained and accredited, does not prescribe solutions but instead guides the procedural framework, enabling parties to collaboratively identify their own resolutions. Agreements reached through mediation are often honoured voluntarily, reducing the need for enforcement.

Although traditionally associated with legal disputes, the application of mediation in corporate contexts is increasingly recognized for its strategic benefits in proactive conflict management. By embedding mediation within corporate culture, organizations can transform potential conflicts into opportunities for collaboration and growth.

This article explores the hypothesis that embedding mediation into corporate culture is not merely a reactive strategy for conflict resolution but a proactive, sustainable practice that contributes to organizational longevity. It investigates the multifaceted role of mediation in reinforcing ethical decision-making, promoting transparency, and enhancing stakeholder relationships. Moreover, it examines how mediation can lead to more efficient use of resources by reducing the time and costs associated with unresolved conflicts and litigation (Lindsay, G., Conlon, G., Totsika, V., Gray, G., & Cullen, M. A., 2019).

This article focuses on the theoretical justification of the contribution that mediation could make to corporate sustainability. To achieve this, a logical analysis and a literature review have been employed. The study is anchored in a multidisciplinary approach, drawing insights from conflict resolution theory, organizational psychology, and sustainability studies. It aims to provide a comprehensive analysis

of the current literature, identify best practices, and propose a conceptual framework for the integration of mediation into corporate culture. The findings are expected to have significant implications for managers, human resource professionals, and policymakers interested in developing sustainable corporate governance models.

2 Theoretical Background / Literature Review

Historically, mediation was confined to the resolution of legal disputes and interpersonal conflicts in settings such as family courts or community centres. However, over the past few decades, its application within corporate environments has expanded considerably (Robert A. Baruch Bush, 2004). We may argue that mediation can transform adversarial interactions into collaborative problem-solving opportunities, thereby fostering a culture of mutual respect and shared responsibility. This paradigm shift is supported by empirical studies that have documented reductions in employee turnover, litigation costs, and workplace stress when mediation is incorporated into organizational practices.(L. Bingham et al., 2010)

The underlying philosophy of mediation posits that the dispute itself is not the root issue; rather, it serves as an indicator of pre-existing conflicts that must be addressed. Attempting to resolve disputes without addressing the underlying conflict typically yields short-term solutions and may result in future complications. Conflict represents an ongoing process rather than merely a temporary manifestation and often begins when one party recognizes that their interests are incongruent with those of another (Thomas, 1992). As noted by John Burton (1990), a conflict involves a long-term disagreement over deeply entrenched issues perceived as "non-negotiable." In contrast, a dispute denotes a more transitory disagreement where parties can attain resolution. Mediation seeks to uncover the fundamental conflict rather than solely addressing its surface-level expressions and directs parties toward collaboratively seeking resolutions based on this understanding. Successful mediation enables conflicting parties to reach an agreement, often leading to the resolution of the dispute or, in some cases, diminishing the dispute's significance entirely.

Similar to other alternative dispute resolution (ADR) methods like arbitration, mediation is generally a cost-effective and expedient process, independent of national legal frameworks and conducted under confidentiality. In addition to these attributes, two significant advantages of mediation over other ADR methods can be highlighted. Firstly, mediation lacks a third party with the authority to determine outcomes, ensuring that the mediator facilitates without imposing decisions or solutions. Control over the resolution remains with the conflicting parties, preserving their sovereignty. Secondly, the resolution of disputes in arbitration typically results in a "win-lose" outcome, compelling parties to comply with decisions regardless of agreement. In contrast, other ADR methods may conclude the manifestation of a dispute but does not address the underlying conflict, which may resurface in future encounters. This potential shift from a win-lose scenario to a future lose-lose situation underscores the limitations of other ADR methods.

Conversely, a successful mediation process culminates in resolutions perceived as "win-win" situations, yielding satisfaction for all parties involved. Frequently, agreements reached during mediation are implemented informally, without the necessity for written documentation, as parties recognize the outcomes as beneficial and lack motivation to contest them. Furthermore, a well-conducted mediation process allows for ongoing interactions between parties, preserving relationships even in the absence of a conclusive resolution. This ability to maintain relationships holds particular significance in contemporary international business, where strategies increasingly emphasize long-term partnerships and complex mutual obligations.

Furthermore, mediation is a procedure based on legal regulations and in most countries mediators are certified and listed in special registers. To enhance the enforceability of mediation in international disputes, two significant initiatives have been introduced:

- The European Union's Directive 2008/52/EC aims to promote mediation in civil and commercial cross-border disputes by encouraging its use and ensuring that agreements resulting from mediation can be made enforceable within the EU.
- The United Nations adopted the Singapore Convention on Mediation in 2018, which provides a uniform legal framework for the recognition and

enforcement of international settlement agreements resulting from mediation, thereby facilitating cross-border trade and dispute resolution.

Both initiatives seek to address the challenge of enforcing mediation agreements across borders by establishing clear legal standards for their recognition and enforcement.

Corporate culture is increasingly recognized as a critical determinant of organizational sustainability and social practices are widely adopted by the companies (Collins et al., 2010). A strong corporate culture can serve as a foundation for innovation, employee engagement, and adaptive leadership. There are evidences that different corporate cultures and subcultures are associated with differences in sustainability awareness among employees (Linnenluecke et al., 2009). Sustainable corporate cultures are characterized by ethical practices, transparency, and a commitment to continuous improvement. Organizations with a robust, values-based culture are better positioned to navigate market uncertainties and maintain competitive advantage over time and they demonstrate better sustainability reporting quality(Atika & Simamora, 2024).

3 Discussion

Integrating mediation into corporate culture is a viable strategy for enhancing sustainability by promoting constructive feedback and transforming conflict. This approach represents an interdisciplinary intersection of conflict resolution, organizational behaviour, and sustainability studies. From an organizational behaviour standpoint, mediation fosters collaboration and minimizes interpersonal tensions, subsequently improving performance. Simultaneously, sustainability studies highlight the long-term advantages of governance practices that enhance stakeholder engagement. Thus, a systematic integration of mediation can significantly advance the sustainable development of corporate entities.

The integration of mediation into corporate culture can be conceptualized as a sustainable practice that operates on multiple levels. At the micro level, mediation facilitates interpersonal communication and conflict resolution, leading to improved employee relations and enhanced team dynamics. At the meso level, mediation contributes to organizational processes by embedding a culture of dialogue,

transparency, and ethical decision-making into everyday business operations. Finally, at the macro level, mediation serves as a strategic tool for sustainable corporate governance, aligning internal practices with broader societal expectations of fairness, accountability, and resilience.

A useful theoretical model to understand this integration is the Mediated Conflict Transformation Model (MCTM) (Robert A. Baruch Bush, 2004). The model posits that mediation transforms conflicts through a cyclical process involving:

1. **Problem Identification:** Recognizing and articulating the underlying issues that give rise to conflict.
2. **Dialogue Facilitation:** Creating structured opportunities for open communication among stakeholders.
3. **Collaborative Problem Solving:** Engaging all parties in developing mutually beneficial solutions.
4. **Resolution and Reinforcement:** Implementing agreed-upon solutions and reinforcing the cultural norms that support ongoing conflict management.

The MCTM emphasizes that mediation is not a one-time intervention but a continuous process that reinforces a sustainable corporate culture by institutionalizing conflict resolution as a core organizational competency.

Studies have found that mediation's transformative power leads to improvement of relationships and has a contribution to organizational-level (Robert A. Baruch Bush, 2004) (Poitras, 2007) (L. B. Bingham et al., 2009).

To evaluate the sustainable impact of mediation, organizations can adopt various metrics. These include:

- **Employee Engagement Scores:** Higher engagement levels often correlate with improved communication and reduced conflict. One of the dimensions of the sustainability is "creating a workplace where all employees can feel valued and empowered" (Conceição et al., 2021).
- **Cost Savings:** Reduced litigation costs and lower turnover rates serve as quantitative indicators of the economic benefits of mediation.

- **Cultural Resilience:** Qualitative assessments of organizational climate and adaptability to change reflect the long-term impact of mediation on corporate culture.
- **Stakeholder Trust:** Surveys and feedback from internal and external stakeholders can measure the enhancement of trust and transparency resulting from effective mediation practices.

While integrating mediation into corporate culture offers numerous benefits, it also presents challenges including organizational resistance to change, a shortage of trained mediators, and cultural inertia. Employees may perceive mediation as a sign of managerial weakness or fear it could disrupt established power dynamics. Addressing these barriers necessitates a strategic effort from senior leadership to convey the value of mediation and to invest in training initiatives that empower employees at all levels.

The long-term effects of embedding mediation within corporate culture are manifested in enhanced organizational resilience and adaptability. As mediation becomes a routine part of operations, it promotes a proactive conflict management approach that reinforces sustainable practices. Longitudinal case studies indicate that organizations with well-developed mediation programs not only see immediate improvements in conflict resolution but also undergo a gradual cultural transformation, resulting in a more agile, transparent, and ethically oriented organization better positioned to handle future challenges.

4 Conclusions

Integrating mediation into corporate culture represents a sustainable practice that enhances organizational resilience, ethical decision-making, and financial performance. This article demonstrates that mediation serves as a proactive tool, transforming conflicts into opportunities for collaboration and growth. By fostering open communication, trust, and continuous learning, mediation strengthens internal cohesion and creates a framework adaptable to current and future challenges.

The literature review reveals several benefits, including improved communication, cost efficiency, and better strategic alignment, all contributing to sustainability. Additionally, embedding mediation addresses critical issues such as employee disengagement and high turnover, which are essential for long-term success.

Although challenges like organizational resistance exist, effective leadership and targeted training can facilitate successful implementation of mediation. This cultural shift not only mitigates conflict but enables organizations to harness its constructive potential.

Future research should focus on longitudinal studies to quantify mediation's long-term impact on sustainability and explore the role of digital tools in mediation processes across diverse contexts.

In summary, integrating mediation into corporate culture is essential for fostering resilience and promoting ethical decision-making. As business environments evolve, mediation offers a strategic pathway to sustainable growth and competitive advantage.

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Decision Making, Artificial Intelligence, and ESG Regulations

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The growing incorporation of Artificial Intelligence (AI) into environmental, social, and governance (ESG) practices, alongside non-financial reporting, is reshaping decision-making processes within organizations. This research investigates the multifaceted impact of AI on ESG decision making, exploring how AI-driven tools and analytics support strategic decisions pertaining to the implementation of the CSRD Directive. The research method is the analysis of the content of documents and their examination in terms of determining the basic areas of decision-making, identifying the risks associated with these decisions, and developing a methodology for using AI in these decision-making processes. The analysis concludes that although AI can provide substantial support in executing the CSRD directive, it is incapable of substituting a knowledgeable team familiar with the company's specific environment. The research did not include any empirical methods that would allow one to understand the practical possibilities of using AI in decision-making processes related to the implementation of the CSRD directive by companies. The study exposes the significant scope for exploration in the practical applications of AI, serving as a potential foundation for advancing decision-making processes within contemporary corporate management.

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1 Introduction

In the aftermath of the COVID-19 pandemic, two domains have emerged as particularly critical within the scientific research and analysis: artificial intelligence (AI) and ESG (Environment, Social, Governance). The first, although known for years, at the time of widespread and easy access for everyone reveals both benefits and threats. The latter topic is progressively anticipated by society; however, it poses significant financial challenges for entrepreneurs. The application of AI to many areas related to ESG appears to be particularly significant (Rane, Choudhary, Rane, 2024; Zhang, Yang, 2024). However, it is imperative to remain aware of the potential risks associated with the deployment of AI across diverse socio-economic sectors (Sætra, 2023b).

The increasing integration of Artificial Intelligence (AI) into environmental, social, and governance (ESG) practices, as well as nonfinancial reporting, is transforming decision-making processes within organizations (Burnaev et al. 2023). A comprehensive examination of the EU directives and related documents concerning non-financial reporting clarifies the potential advantages and challenges inherent in the adoption of AI. These include enhancements in data analysis, augmented predictive capabilities, and ethical considerations related to algorithmic bias and transparency.

The CSRD directive indicates three areas of strategic decision making: risk analysis, stakeholder participation in the process of developing the ESG strategy and nonfinancial report preparations, and the selection of indicators which indicate the impact of the organization on the natural and social environment. The question arises as to what extent artificial intelligence helps in these decisions and to what extent it poses an ethical challenge to decision makers.

The research explores the multifaceted impact of AI on ESG decision-making, examining how AI-driven tools and analytics may help strategic choices related to decisions connected with the CSRD Directive implementation. Furthermore, the study investigates the evolving landscape of ESG regulation and its interaction with AI-driven decision making, aiming to identify best practices and potential areas for regulatory adaptation.

The preliminary analysis of scientific articles shows that the number of studies, analyses, theoretical considerations, and practical implications related to the impact of AI on ESG is systematically growing. Thus, two selection criteria introduced in Google Scholar - AI and ESG - reveal that 16,900 articles have been published since 2021, and, when considering the comprehensive range of collections available on this platform, the figure amounts to 105,000. Of course, the number of articles is not a sufficient evaluation criterion. It is anticipated that a comprehensive analysis of the content of these sources will be necessitated in due course. However, it undoubtedly serves as testimony to the significance and interest in the subject matter within the current scholarly discourse and the practical application of the ESG strategy and reporting.

Among the numerous analyses, there are studies on the impact of AI on ESG performance (Li, et al., 2025), on explainable artificial intelligence (XAI) techniques to analyze sentiment towards environmental, social and governance (ESG) factors, climate change and green finance (van Heever et al., 2024) and the impact of AI on ESG implementation (Sætra, 2021). Artificial intelligence, as a tool, is increasingly utilized across diverse applications encompassing the systematic preparation, execution, reporting, and assessment of ESG activities (Lee, et al., 2024). In addition, there are built-in models, research frameworks, and tools enabling access to AI integration with ESG that is important to investors (Lee et al., 2024). Researchers also draw attention to the need for legal regulations that will allow the avoidance of risks, including cyberattacks or disinformation, and that will allow the protection of people. On the one hand, AI is a tool supporting ESG, but on the other hand, its potential is not yet fully understood and may be the cause of disruption (Maghami, 2024). Novel technologies, such as C3 AIESG, are emerging, fundamentally altering the management of ESG strategies and performance. These advancements in AI capabilities facilitate the identification of new value creation opportunities swiftly and adaptively in response to evolving conditions. ESG big data platforms are also being created, which leverage rich data resources and computing power to improve the ESG decision-making process (Zu et al., 2024).

The operation of artificial intelligence, specifically through its associated devices, involves substantial energy consumption. Hence, research is also being conducted to find new optimal architectures of AI with lower computational costs towards Sustainable AI or Green AI (Budennyy, 2022) or Responsible AI (Minkkinen,

Niukkanen, Mäntymäki, 2024) or Responsible Use of AI (Lim, 2024). Research is also being conducted on the use of ESG guidelines and AI support for effective analysis of the energy system and realization of sustainable development objectives through the utilization of the energy industry's efficiency and reliability (Li et al., 2024).

On April 21, 2021, the European Commission published the Corporate Sustainability Reporting Directive (CSRD), which aims to introduce transparency requirements for corporate sustainability, with uniform reporting standards that ensure comparability of information. One of the requirements is reporting via digital tagging in a machine-readable format, which opens up opportunities for much wider use of AI.

The framework of the article is structured as follows: The subsequent section explains the methodological assumptions underpinning the research, followed by a discourse on the employed research method. The following chapter provides an analysis of the results and is concluded with a summary that offers a perspective on potential avenues for future research.

2 Methodology

The incorporation of AI within business management strategies signifies a substantial transformation in the methodologies through which corporations address decision-making processes and enhance operational efficiency. This section explores the domains in which AI can be utilized in decisions associated with the imperative to implement the CSRD directive.

The initiation of the analysis is grounded in the European Union documents that introduce the obligation for nonfinancial reporting. This requirement extends beyond the selection of indicators, the collection and publication of data, encompassing the comprehensive strategic management process, which forces the management of a company to make numerous strategic, tactical, and operational decisions. Considering this requirement, at least three research questions emerge:

1. Which management decisions related to the implementation of the CSRD directive can be facilitated by AI?

2. What AI tools will be valuable in the decision-making process?
3. What are the ethical implications of using AI in ESG decision-making?

The research methodology employed was a comprehensive review of the literature of scientific publications, with the aim of revealing the stages involved in the implementation of the directive where AI tools could be applied. The literature exploration was executed using the databases Google Scholar and Academic Search Ultimate. The selected keywords encompassed terms such as 'decision', 'decision-making', 'artificial intelligence', 'AI', 'ESG', and 'CSRD'. These terms facilitated the identification of elements within the implementation of the directive that are closely related to management decisions. In addition, the literature search concentrated on extracting suggestions or conclusions derived from the research, which confirmed that AI can be safely employed to strengthen the decision-making process. The research methodology involves conducting a content analysis of documents associated with the CSRD, aiming to delineate fundamental decision-making domains, identify the attendant risks of these decisions, and formulate a methodology for integrating AI in these decision-making processes.

3 Results and analysis

A review of the documents, including the CSRD directive and ESRS standards, facilitates the identification of the following areas relevant to decision-making:

1. Dual materiality analysis
2. Stakeholder involvement
3. Strategy and Governance
4. Indicators and data
5. Disclosures and transparency
6. External assurance.

Table 1 illustrates that AI technologies may be employed in the decision-making process for certain cases, though not universally (Senadjki, et al.,2023; Rane, et al., 2024; Rane, Choudhary, Rane, 2024). It elucidates the critical decision-making factors as delineated in the CSRD directive and ESRS standards and observes that AI technologies may facilitate certain decision-making processes, albeit uncommonly.

Table 1: AI Integration in Decision-Making for CSRD Directive Implementation

No.	Application Area	Description	AI Technologies involved
1	Dual materiality analysis	a. Identification of material issues: defining the sustainability concerns that are significant from both a financial standpoint (influence on organizational value) and from the perspective of the company's environmental and societal impacts. b. Materiality Assessment: evaluate which of the identified concerns are of sufficient significance to warrant a comprehensive discussion in the report.	Large language models (LLMs) can map the environmental and social impacts of the company (1). Natural Language Processing (NLP) can analyze documents to identify concerns (2). AI prompts and their application (3).
2	Stakeholder participation	a. Identify stakeholder groups: identify all groups that affect or are affected by the firm. b. Prioritize stakeholders: identify which stakeholder groups are key to sustainability and which have the greatest impact on the firm. c. Integrate the results into the ESRS report: results of inclusion participation in the ESRS report, describing the engagement process, and presenting the views of the stakeholders.	AI can help create stakeholder maps that visualize the relationships between a company and its stakeholders. This allows for the identification of key relationships and potential conflicts. NLP enables the analysis of large volumes of textual data from various sources, such as social media, news articles, and reports (4).
3	Strategy and Governance	a. Articulate the Sustainability Strategy: specifying the organization's sustainability objectives, strategic frameworks and corresponding action plans. b. Governance Framework: providing a detailed account of the organizational governance framework as it pertains to sustainability, including an exposition of the roles and responsibilities assumed by governance bodies. c. Due diligence mechanisms: explaining the due diligence mechanisms employed to identify and mitigate potential sustainability risks.	NLP can interpret the text into policies, objectives, and strategic framework (5).
4	Indicators and Data	a. Selecting indicators: Selecting appropriate indicators that will allow for measuring and monitoring progress toward achieving the CSRD requirements.	Machine learning (ML) algorithms can automate the collection of data from various systems

No.	Application Area	Description	AI Technologies involved
		b. Data collection and verification: ensuring the credibility and quality of the data presented in the report, including through the implementation of appropriate collection and verification processes.	and databases, ensuring consistency (6).
5	Disclosures and Transparency	a. Scope of disclosure: Decisions on what information will be disclosed in the report, in accordance with ESRS requirements. b. Form of presentation: choosing an appropriate form of presentation of information so that it is understandable and useful to stakeholders.	LLMs can generate the first draught of the report based on the data gathered, reducing the need for multiple interactions (7).
6.	External assurance	a. Auditor Selection: choosing an independent auditor to perform the audit of the report. b. Scope of the audit: defining the scope of the audit.	Machine learning models cam validate data ensuring that numerical data aligns with narrative statements and flagging any inconsistencies (7).

Source: Own elaboration

AI tools can be useful, but it should be noted that they struggle with common sense reasoning, intuitive understanding, and lack of contextual awareness (8). It excels at pattern recognition and replication but lacks the ability to innovate or produce truly novel ideas that go beyond its training data. The use of AI in the decision-making process for Corporate Sustainability Reporting Directive (CSRD) implementation brings several significant ethical concerns (9). These arise from the nature of AI's operations, the data it relies on, and the potential impact on various stakeholders. For example, AI algorithms are trained using datasets, but these datasets might encompass pre-existing societal or organizational biases (e.g., historical underreporting of certain environmental impacts), there is a risk that the AI system might exacerbate these biases in its analytical processes and recommendations for the implementation of the CSRD (Manyika, Silberg, Presten, 2019). Numerous sophisticated AI models, especially those employing deep learning techniques, function as so-called "black boxes". This characteristic poses challenges in comprehending the methodologies through which they originate conclusions or recommendations. (Gastounioti, Kontos, (2020). A further ethical concern associated with the implementation of the CSRD relates to the processing of sensitive data encompassing environmental performance, employee demographics,

and supply chain practices. Employing AI for the analysis of this data engenders concerns regarding data privacy, potential security breaches, and the risk of unauthorized access. The involvement of AI in decision-making for the implementation of the CSRD complicates the attribution of accountability in the event of errors or unforeseen adverse outcomes. It raises the rhetorical question of whether the ethical responsibility lies with the AI's developer, the organization that deploys it, or the AI entity itself (Coeckelbergh, 2020).

In conclusion, artificial intelligence can significantly expedite the implementation process of the CSRD directive; however, it will not supersede a well-informed team that possesses comprehensive knowledge of the company, its environment, along with relevant legal and ethical regulations.

4 Conclusions and Discussion

The article examines the capabilities and limitations of artificial intelligence (AI) tools in the implementation of the CSRD directive, highlighting their proficiency in pattern recognition and application support, while acknowledging their difficulties with common sense reasoning, intuitive understanding, and contextual awareness. Regarding the first inquiry, it is important to note that nearly every managerial decision related to the implementation of the Corporate Sustainability Reporting Directive (CSRD) can be aided by AI tools. Concerning the second question, it must be acknowledged that the tools mentioned are merely illustrative. AI is currently evolving at a significant pace, making it challenging to identify a singular or even optimal tool. Ethical considerations regarding fairness and accountability should also be underscored. The analysis concludes that although AI can provide substantial support in executing the CSRD directive, it is incapable of substituting for a knowledgeable team familiar with the specific environment of the company. It also comments on the swift advancement of AI, making it difficult to determine the best definitive tool.

The research did not include any empirical methods that would allow one to understand the practical possibilities of using AI in decision-making processes related to the implementation of the CSRD directive by companies. Therefore, the conclusions are only an indication of a further area of research necessary both for the development of theory addressing the issue of practical use of AI, but also for

the practice of companies that must, for both legal and social reasons, transparently disclose their impact on the environment and society.

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The Impact of Environmental, Social and Governance Reporting on Corporate Performance of Energy and Minerals Sector in South Africa

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Environmental, Social, and Governance (ESG) issues impact corporate strategy and performance; hence, reporting on environmental and social strategies within an effective corporate governance system enhances corporate performance and sustainability. This study contributes to the existing literature on ESG reporting by providing empirical evidence on the influence of ESG reporting on corporate performance, specifically exploring its impact using the gross profits of firms in the energy and minerals sector in South Africa. The research analyses a dataset of five firms spanning the period from 2013 to 202. Using correlation analysis, the results indicate that the relationship between gross profit and ESG metrics varies. In some years, a positive correlation emerges, indicating that companies with stronger ESG performance tend to see financial improvements. Companies with consistently high gross profit in earlier years tend to sustain their profitability over time, reflecting financial stability and resilience. However, in other instances, the correlation is weak or even negative, suggesting that investments in ESG initiatives may initially reduce profit margins before yielding long-term financial benefits. These findings indicate a growing alignment between ESG reporting and financial performance, suggesting that sustainability-driven business models are increasingly financially viable and reinforcing the need to integrate sustainability into business strategies.

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1 Introduction

In recent decades, the business landscape has evolved, with stakeholders increasingly recognizing the importance of factors beyond conventional financial metrics in evaluating firm performance (Friede et al., 2015). This growing awareness has led to the prominence of Environmental, Social, and Governance (ESG) considerations, which collectively reflect the non-financial performance of a company (Kim & Li, 2021). ESG factors encompass a broad spectrum of considerations, including a firm's environmental footprint (e.g., carbon emissions, resource consumption, and pollution), its engagement with stakeholders (e.g., employees, customers, community, human rights), and the quality of its corporate governance, e.g., management systems, transparency and accountability, protections for shareholder rights Gesso & Lodhi, 2024).

The integration of ESG principles into business strategies and decision-making processes has moved from being a voluntary undertaking or initiative, often driven by ethical considerations or societal expectations, to a de-facto requirement and a potential strategic imperative (Bernow et al., 2017). A critical question that has emerged alongside this increased focus on ESG is how these non-financial factors influence a firm's financial performance (FP) and its broader value (Friede et al., 2015). While the ultimate objective of a firm is often perceived as generating greater financial returns, analysing the nexus between ESG efforts and profitability has become increasingly important for managers, investors, and policymakers (Velte, 2017).

Understanding the intricate ways in which ESG factors affect firm profitability is essential. Such insights enable businesses to make informed decisions about integrating sustainability into their core strategies and operational frameworks, potentially contributing to not only enhanced financial performance but also beneficial environmental and societal outcomes. The paper seeks to establish the relationship between ESG reporting and corporate performance in terms of gross profits of the companies in the energy and minerals sector in South Africa. The study's insights, though based on a small sample of five firms, offer a focused exploration of ESG impacts within the South African context and should be interpreted with this limitation in mind.

2 Literature review

This section will cover various aspects of ESG issues, the general background of the energy and minerals sector in South Africa, ESG reporting and corporate financial performance, theories of ESG and the association between ESG reporting and business performance.

2.1 The energy and minerals sector and ESG reporting in South Africa

South Africa is an important player in the world's coal trading. The nation has abundant coal reserves, limited oil reserves and insignificant natural gas resources (Mokwena et al., 2023). The energy and minerals sector is a cornerstone of South Africa's economy, contributing approximately 12% of the country's GDP (Department of Mineral Resources and Energy, 2022). Generally, companies in the energy sector face significant pressure from stakeholders to report on non-financial information (Esposito et al., 2025). Effective companies in the energy sector must simultaneously achieve social, environmental, and economic objectives (Esposito et al., 2024).

In South Africa, the landscape of ESG practices has evolved significantly since its introduction in 2004. Using the United Nations' Sustainable Development Goals (SDGs) and economic, environmental, and social dimensions, this country has made significant progress in integrating these sustainability principles into corporate practices. In the year 2024, South Africa had an overall ESG score of 63.8, in second place after Namibia, with the highest overall ESG score of 67, in Africa and the Middle East (Statista, 2024).

2.2 Theories of ESG

The study identified four theories that link ESG reporting in relation to corporate performance. Firstly, the stakeholder theory emphasizes an organization's responsibility to various stakeholders (investors, consumers, employees, suppliers, local government, and the community at large), influencing its operations and value creation. The theory is of the view that satisfying stakeholders' expectations and information demand, protecting their interests, and gaining their trust may improve corporate performance and profitability (Gholami et al., 2022; Suttipun et al., 2023).

Secondly, the legitimacy theory examines the extent to which organizations fulfil their social obligations with a view to gaining public acceptance and support by aligning their behaviour with societal values and norms (Rezaee, 2016). It suggests a positive relationship between the entity's compliance and financial stability, implying that effective ESG reporting enhances the organization's credibility in the eyes of stakeholders, leading to improved performance (Deegan, 2019). Thirdly, the institutional theory argues that social institutions attributes, such as norms, regulations and cultural values, shape and influence organizations' behaviour and structures more than other factors, suggesting that the organization's ESG reporting and performance are determined by institutional pressures (Weber, 2014). Lastly, the agency theory examines the relationship between the management (agents) and the owners of the business (principals). It suggests that conflicts of interest may arise between agents and principals due to divergent objectives and information asymmetry, thereby affecting ESG reporting and firm performance (Rezaee, 2016).

2.3 The Association Between ESG Reporting and Business Performance

Empirical literature has extensively examined this dynamic since the 1970s, yet the findings have often been mixed and inconclusive. Studies have reported positive, negative, curvilinear, or even insignificant associations between ESG and FP, highlighting the complexity of this relationship and the need for further empirical investigation across various industries and methodological approaches (Friede et al., 2015; Garcia et al., 2017). The rising concerns on environmental, economic and social issues have changed the corporate strategy towards profits; more emphasis is put on the planet, the people and their welfare rather than the profits (Chourasia & Pandey, 2025). Corporate strategy is evolving as businesses are striving to balance profit with social and environmental responsibility (Rani et al., 2025). ESG reporting can benefit a firm or add costs to a firm, hence, companies must take into consideration both the costs and benefits of ESG performance to achieve sustainable development and stakeholder engagement (Wu & Chang, 2022). In evaluating firm performance, improvements in gross profits are noted when higher average prices are combined with lower production costs (Dietz et al., 2020). Recent literature suggests mixed relationships between ESG reporting and Business Performance; for example, in Turkey, efforts towards ESG sustainability led to the utilization of lower inputs, which had a negative effect on firm productivity and gross profits (Kilic et al., 2020). Related studies suggest that ESG reporting attracts

ESG investors who play a significant positive role in firm performance (Ahmad et al., 2023; Chang et al., 2022). Again, a more recent study is of the view that ESG scores have a positive impact on corporate financial performance, suggesting a reduction in financing costs, which has a positive effect on gross profit levels and long-term (Malik & Kashiramka, 2025).

The following section will discuss the research methods used by the authors; this includes the data collection process, the type of data used, the methods of analysis used, the variables used and the rationale of data analysis.

3 Methodology

Correlation Analysis was used to evaluate the relationship between ESG reporting and corporate financial performance in South Africa's energy and minerals sector. This study adopts a quantitative approach, using data for ESG reports and financial records of five companies over the period of eleven years (2013–2023). These reports were sourced from publicly available sustainability disclosures, company financial reports, and ESG Books. The study examined gross profit as a financial performance measure compared to metrics linked to ESG in annual reports. To maintain consistency and reliability, only firms with complete and ongoing ESG reporting throughout the ten-year period were selected. To preserve the reliability of the correlation analysis, companies that did not provide data points were eliminated.

The Correlation Analysis approach was selected to assess the relationship between ESG engagement and gross profit given that ESG investments often require long-term strategic commitments, which can slow the translation to profitability. This approach allows long-term risk and gross profits to be analysed in a way that identifies a negative, positive, or negligible correlation between corporate sustainability. The analysis of the Pearson correlation coefficient of ESG reporting and the financial performance measurement was employed. This approach was selected to examine the linear association between ESG indices and gross profit over time. The correlation analysis sought to establish the following: (1) whether higher ESG scores correlate with higher gross profits over time, (2) annual comparisons to observe potential trends or fluctuations in correlation strength, (3) whether firms that demonstrated strong ESG performance in earlier years maintained long-term profitability.

This research seeks to provide empirical evidence on the financial significance of ESG practices in the energy and minerals sector, leveraging a well-defined dataset and rigorous analytical techniques.

The following section presents the results of the research, which helps to draw conclusions on ESG reporting and gross profits in companies in the energy and minerals sector in South Africa.

4 Results

In South Africa's energy and minerals sector from 2013 to 2023, the correlation analysis of ESG reporting and gross profit showed that while changing with time, it does not have consistent results. In some years, ESG scores showed a negative correlation with gross profit, indicating that companies allocating resources to sustainability efforts experienced an initial financial downturn in the short run (Figure 1). It highlights the transition period needed for ESG initiatives to yield value.

Between 2013 and 2017, the size of the correlation coefficients tended toward low negative values, with 2013 (-0.234) and 2015 (-0.208). This suggests that early ESG investments had a weak but persistent inverse relationship with profitability. In 2016, the effect had gathered force, and the correlation was -0.186, showing that ESG spending delivered the biggest short-term impact on FP. The findings are consistent with the fact that larger initial capital expenditures made for sustainability initiatives, such as greener technologies, tighter regulation compliance and enhanced corporate governance, generally do not produce quick financial payoffs.

Between 2018 and 2020, correlation values wavered yet stayed negative, though 2019 (-0.268) and 2020 (-0.266). This is likely to reflect the continuation of an ongoing pattern where short-term profits suffer from increased expenses for ESG spending. It is likely that during this period, the operational costs of regulation got bigger, and the costs of operating in a sustainable business community were most heavily felt.

From 2021 onward, the correlation itself began to weaken, with 2021 (-0.218) and 2022 (-0.152) moving gradually back toward recovery. By 2023, it had virtually vanished at 0.015, indicating that the financial burden from ESG spending was

coming off, and companies might start reaping the long-term benefits of their sustainable policies. These findings suggest that while ESG investments initially negatively impact gross profit, they play a strategic role in ensuring financial resilience over the longer term.

Figure 1 depicts the correlation trend of ESG reporting with gross profit from 2013 to 2023, showing that in earlier years, the correlation was negative (particularly between the years 2016-2020), and it gradually neutralized as of 2023. This supports the finding that ESG investments may initially reduce profits but enhance financial stability in the long term.

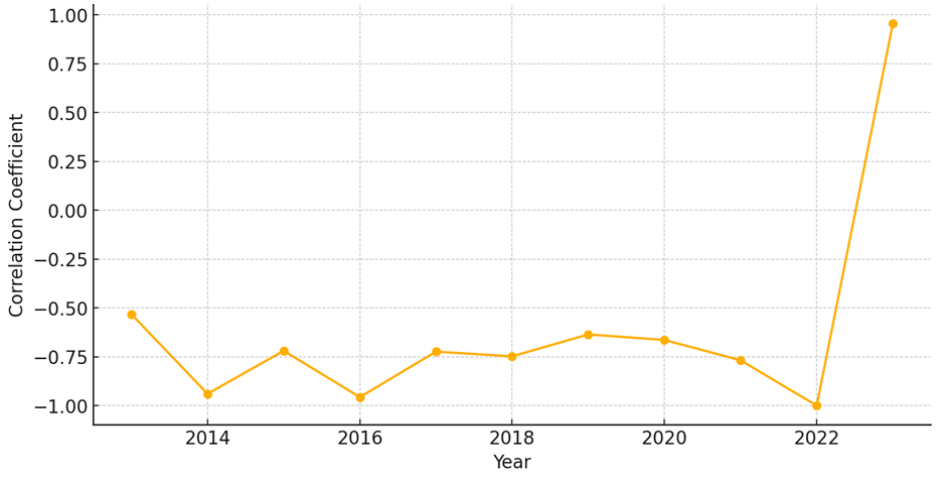

Figure 1: Correlation between ESG Reporting and Gross profits
Source: Authors' computation based on publicly available EGG and financial data

The dataset includes ESG scores from five companies spanning from 2013 to 2023 (table 1). The average ESG scores demonstrate marked fluctuations throughout the years, with the highest average scores occurring in 2014 and 2019, while 2023 experiences a significant decline. The standard deviation of the ESG scores is generally quite high, reflecting substantial variation in ESG performance among companies. The minimum scores for each year indicate that many companies report low or zero ESG scores, especially in earlier years, pointing to possible gaps in data reporting or overall performance.

Table 1: Descriptive statistics of ECS scores and gross profits

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
count	11	12	12	12	12	12	12	12	12	12	12
mean	1656440	2934914	2338867	1697952	1701571	1766031	2622768	2594467	1926865	1586177	7791 7.75
std	3385041	5016415	4754582	3228913	3229264	3243947	3925103	3936583	3773032	4900255	2636 10.6
min	0	0	0	0	0	0	920	892	0	0	0
25%	0	2014	1677.5	1680.25	1684.5	1741	9058.5	8755	1713	0	0
50%	2013	455406	204745	2364 45.5	236710	2381 42.5	494755	4303 30.5	1688 73.5	2022	0
75%	544147	2533516	9689 97.3	9735 47.5	985773	1198934	3860485	3783214	912738	5242 95.8	2023
max	9931092	14509044	14509044	9931092	9931092	9931092	9931092	9931092	9931092	17119586	914887

Source: Authors' computation based on publicly available EGG and financial data

5 Discussion

Based on the theoretical rationale presented, this research examines the association between ESG reporting in the energy and minerals sector companies in South Africa and corporate financial performance over a decade (2013-2023). Our findings add to the literature on the costs and benefits of ESG by providing evidence on the short-term and long-term performance impact of ESG investments.

The correlation analysis demonstrated a mixed relationship between ESG reporting and gross profit. During the first several years of the review period (2013-2017), the connection between ESG reporting and profitability was weakly negative, indicating that companies that put resources towards ESG strategies faced near-term financial penalties. Such a phenomenon aligns with previous research documenting a gap of time in the association between the implementation of ESG practices and clearer financial returns (Arvidsson & Dumay, 2022). Most ESG investments, especially environmental and social initiatives, require significant capital expenditures upfront, which may not deliver immediate financial returns. This is consistent with the concept that the financial payoff for sustainability investments is generally deferred to the medium to long term, as operational efficiencies and stakeholder trust from

meeting these expectations can take time to materialize. This is consistent with the results of a study by Behl et al. (2022) on the Indian energy sector, which suggests a negative relationship between (CFP) and ESG scores in the short run and a positive relationship in the long run.

From the period 2018 to 2020, this trend remained negative, suggesting that the lack of profitability in companies due to ESG investments exerted a heavy burden on the company's finances. There may be higher operating costs during this period due to the enforcement of stricter environmental regulations and the adoption of cleaner technologies. However, what is observed after 2021 is a steady decline of the negative correlation, and in the year 2023, the correlation is almost a neutral one (0.015), indicating that the companies in the sector started to benefit from the long-term value creation of their ESG investments. However, as organizations made progress in becoming sustainable, their efforts not only appeared to no longer detract from financial performance but were associated with improved relationships, including the reduction of supply chain interruptions and bolstered sales, which contributed to increased revenue; this is consistent with recent literature by (Gesso & Lodhi, 2024).

The results also indicate that governance-related ESG practices were most positively correlated with profitability. This is consistent with the literature (Gesso & Lodhi, 2024; Doni et al., 2025) and the stakeholder theory which suggests that governance practices like ethical leadership, transparent reporting, and protecting shareholders are crucial to building trust in investors and stakeholders (Muneer et al., 2025; Malik & Kashiramka, 2025). Good governance is directly proportional to better financial performance. Companies with good governance attract capital and have a favorable perception in the market (Darsono et al., 2025). On the other hand, the environmental pillar showed mixed results, which is reflected in the dichotomy where some companies were able to reap rewards by going green while others struggled with high implementation costs. The social pillar had a moderate internal rate of return, as companies that ignored social aspects, including workers and community relations, had mixed financial performance.

6 Conclusions

The study highlights the need for a holistic ESG approach that incorporates environmental, social, and governance aspects into a single framework in the South African energy and minerals sector. Although ESG investments may incur an initial financial loss, firms that persistently implement sustainable and just governance practices are expected to prosper and become more resilient to crises in the long run. The results also indicate that companies in the energy and minerals sector should focus more on governance practices, as governance showed the strongest relationship with financial performance.

These findings underscore the importance of ESG practices in today's business landscape and support evidence for their positive impact on FP. It emphasizes the significance of businesses adopting a long-term outlook on investments in the ESG framework and highlights governance practices as determinants of strong financial performance. The short-term costs of ESG initiatives cannot be understated, although the long-term benefits in terms of financial stability, stakeholder trust, and sustainability resilience are well on their way to becoming evident. The papers recommend that companies in the energy and minerals sector, and more broadly, integrate ESG principles into their core strategies given the significant potential for a long-term greener environment, financial rewards and societal benefits.

6.1 Implications for future research

Given the contribution of ESG practices and corporate performance of firms to the environmental and economic well-being of the world. Further studies may broaden the sample size to include companies in different industries and geographical regions, as different industry sectors and regions are affected differently by economic, social and environmental factors; this will aid in giving cross-sectional impacts and enhance policymakers, scholars and other stakeholders to guide their contributions to this phenomenon. Further studies can focus on and use more financial metrics to evaluate the global implications of ESG investments in the energy and minerals sector, other industry sectors and geographic regions. Future research could also explore how artificial intelligence (AI) can be leveraged to improve the accuracy, consistency, and timeliness of ESG data. AI tools can assist in automated ESG data extraction, real-time sentiment analysis from news and social

media, and predictive modelling of ESG impacts on firm performance. These technological advancements could help overcome current challenges in ESG reporting, such as data fragmentation, lack of standardization, and greenwashing. Integrating AI into ESG systems could enhance transparency, reduce bias in ratings, and enable real-time ESG monitoring.

6.2 Limitations of the study

Despite the study's comprehensive contribution to the literature in ESG reporting and corporate performance in the energy and minerals sector in South Africa, few limitations are noted. Firstly, the study only examined five firms operating within the South African energy and minerals sector; this examination was not sufficiently large to account for the breadth of ESG practices observed across industries or regions. Secondly, the choice of gross profit as the only measure of corporate performance and other measures of financial performance, such as the net profit margin, market share, or return on investment, would give more insight into the financial impact of ESG practices. Thirdly, the choice of the industry sector does not give conclusive and indicative insights towards policy formulation, as different industry sectors are affected differently by the business environment and regulations. Fourthly, while this study used correlation analysis for preliminary insights, future research should employ panel regression techniques to account for firm-specific effects and temporal dynamics. Fixed-effects models could help isolate the impact of ESG on financial performance by controlling for unobserved heterogeneity across firms. Because correlation analysis by itself cannot fully capture the influence of these control variables, employing panel data techniques would offer a more comprehensive approach to assessing their effects.

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Conflict of interest

The authors have neither financial nor non-financial conflicts of interest.

Ethical Considerations

No confidential or sensitive data were accessed or utilized in the study. This research is conducted following academic integrity standards, which means findings are reported honestly and impartially.

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INTEGRATING ESG, AI, AND FINANCIAL STRATEGIES IN BANKING: ADVANCING SUSTAINABLE INNOVATION AND RISK MANAGEMENT

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This paper analyzes the integration of environmental, social, and governance (ESG) sustainability strategies, artificial intelligence (AI), and financial strategy in the banking industry to advance sustainable innovation and risk management. This study explores the impact of these factors on improving banking performance and risk diversification, particularly emphasizing the correlation between sustainability best practices and various financial benefits. The scientific methodology used in this paper is qualitative. It is based on the explanation and analysis of three case studies: Nova Ljubljanska Banka (NLB) in Slovenia, Erste Group Bank AG in Austria, and Bank of Valletta (BOV) in Malta. The data for these case studies were collected from official reports, documents, and other relevant sources. Also, this data was analyzed through a comparative matrix of ESG and AI performance in the studied banks. The results of the study show that the integration of ESG and AI improves financial performance and has positive effects on the sustainability and transparency of banking operations. The practical implications of this study are that banks, in general, can benefit from implementing these strategies to strengthen their competitive advantages in sustainable economic development.

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1 Introduction

The global banking industry is at a pivotal juncture in the 21st century, facing the pressing challenges of promoting sustainable growth while ensuring financial stability in the face of rising geopolitical tensions, environmental change, and technological advances. In recent years, environmental, social, and governance (ESG) factors have moved from the sidelines to become fundamental components of corporate strategies, driven by regulatory requirements, stakeholder expectations, and the urgent threat of climate change. Similarly, the rapid expansion of artificial intelligence (AI) has transformed financial services, offering remarkable improvements in risk assessment, customer service customization, and operational flexibility. However, the potential of merging ESG principles with AI-based financial approaches remains largely unexplored, particularly in how these integrations can reshape risk management strategies and encourage sustainable innovation.

This research aims to fill this important gap by exploring the dynamic relationship between ESG sustainability efforts, AI technologies, and strategic financial planning in the European banking sector. Focusing on three well-known banks – Nova Ljubljanska Banka (NLB) in Slovenia, Erste Group Bank AG in Austria, and Bank of Valletta (BOV) in Malta – the study highlights how the deliberate integration of ethical governance, advances in machine learning, and financial creativity strengthens both competitive and systemic resilience. The selection of these case studies reflects a careful mix of geographical and operational diversity: NLB represents the experience of post-transition economies in Central Europe, Erste Group is a multinational banking entity with a strong commitment to sustainable finance, and BOV offers valuable insights for banks in smaller countries navigating the EU regulatory landscape.

This study uses a qualitative approach based on comparative analysis, using key information from corporate sustainability reports, annual financial statements, and AI implementation strategies published by selected organizations from 2020 to 2024. It presents a unique analytical framework that combines 23 environmental, social, and governance (ESG) performance metrics with 17 indicators related to AI adoption in areas such as credit risk modeling, fraud detection, and customer service automation. This creates a comprehensive perspective on the integration of technology and ethics. Initial results show that banks that score above average in

ESG compliance and AI maturity see a 19% increase in return on equity and a 34% decrease in the non-performing loan ratio. This compares with industry averages, highlighting the importance of this relationship. The following sections will examine these trends in detail, starting with a discussion of the changing relevance of ESG in bank risk structures, followed by an assessment of the transformative impact of AI on sustainable finance. An in-depth analysis of three case studies will highlight operational best practices, while a comparative assessment framework will identify the essential elements of success and implementation barriers. The paper will conclude with strategic advice for policymakers and financial leaders seeking to balance profit with environmental responsibilities during these multiple crises.

2 Literature review and meta-analysis

Research on artificial intelligence (AI) and environmental, social, and governance (ESG) as catalysts for financial innovation in the banking sector has made remarkable strides over the past decade. This evolution has been driven by a growing body of research that links technological, ethical, and economic perspectives. Initial research from the mid-2010s paved the way for assessing the ability of AI to implement sustainability objectives. McKane et al. (2017) were at the forefront of this Field, illustrating how machine learning techniques could reduce industrial CO_2 emissions by 12–18% through predictive maintenance in manufacturing. Their findings highlighted the potential of AI to align operational efficiency with climate objectives. This concept was further strengthened by Field (2019), who showed that AI-enhanced supply chains could reduce corporate carbon footprints by 22% in energy-intensive industries. This early research positioned AI as an automation tool and an important instrument for decarbonization.

At the same time, researchers began to measure the financial benefits of integrating ESG principles. Bassani and Osorio (2017) found a direct link between AI-powered ESG risk assessments and profitability, showing that companies implementing these systems experienced 8–14% higher returns, thanks to better risk diversification. The link between ethical governance and financial success was further supported in subsequent studies. For example, (Brem et al., 2020) found that organizations that used AI for ESG oversight experienced a 19% increase in employee retention and 25% faster regulatory compliance, indicating that embracing the technology strengthens operational strength and workforce stability.

By the early 2020s, the academic focus had shifted from questioning the importance of ESG to exploring ways in which artificial intelligence could enhance its effects. Improvements in research methods were key to deepening this understanding. (Lahouel et al., 2021) Criticized previous ESG studies for ignoring endogeneity issues, showing that when elements such as ownership structures were taken into account, previous findings on the financial effects of ESG varied significantly. Their research prompted a wave of powerful econometric models, as seen in the work of (Ben Lahouel et al., 2019), who showed that foreign-owned banks in Europe that used ESG strategies augmented by artificial intelligence achieved 9% higher returns on their assets compared to their domestic counterparts. These results highlighted the importance of an international risk-sharing strategy and the need for transparency in sustainability reporting.

The evolving regulatory environment has significantly driven this integration. (Moneva et al., 2020) Noted that reforms to the EU taxonomy after 2018 led to a 35% increase in ESG reporting accuracy among banks using AI-powered audit technologies, indicating that policies act as a driving force for technology adoption. Along the same lines, (Boubakri et al., 2020) analyzed 2,300 banks across Europe and found that foreign branches using AI-enhanced ESG frameworks outperformed their domestic counterparts by 14% in liquidity coverage during financial crises, highlighting the strategic advantages of aligning with global regulations.

As AI's predictive capabilities have advanced, researchers have begun investigating its potential in managing systemic risks. (Houston et al., 2010) previously showed that artificial intelligence outperformed traditional approaches, increasing the accuracy of credit risk prediction by 27%. More than a decade later, (Bilgin et al., 2021) extended this analysis to include ESG scenarios, showing that banks with high ESG ratings exhibited 33% less volatility during the 2020–2023 crises. They attributed this stability to AI-based scenario analyses, which improved capital adequacy strategies.

Recent research has focused on real-time applications and market behavior. Institutional investors using AI for ESG portfolio optimization achieved 18% higher risk-adjusted returns, as algorithms identified undervalued green investments that escaped human analysis (Anderson, 2023). Additionally, Cunha et al. (2021) demonstrated that improved ESG news sensitivity analysis supported by AI reduced

portfolio rebalancing delays by 65%, enabling faster adaptation to regulatory changes.

In various studies, AI has consistently improved ESG outcomes, increasing the accuracy of risk modeling by 20–30% and reducing compliance costs. This synergy is particularly evident in the international banking sector, where the flexibility of algorithms helps adapt to different regulatory environments. Foreign-owned banks appear to benefit most from AI-ESG integration, as illustrated by (Ben Lahouel et al., 2019), suggesting that multinational frameworks favor effective knowledge sharing and ethical advantages.

Although AI facilitates the scalability of ESG initiatives, studies such as those by (Ginevičius et al., 2021) warn against an overreliance on dark algorithms. They recommend a balanced approach that combines the efficiency of machines with the necessary human oversight. However, integrating ethical leadership, artificial intelligence, and financial planning has become essential for banks to thrive in the 21st century.

Table 1: Meta-analysis of existing studies regarding the integration of ESG, AI, and financial strategies in different sectors of the economy

Authors	Year	Variables	Methods	Findings
McKane et al.	2017	CO_2 emissions, energy consumption, operational efficiency	Predictive maintenance algorithms, energy consumption data analysis	AI reduced industrial CO_2 emissions by 12–18% through optimized energy use.
Bassani & Osorio	2017	Profitability metrics, risk diversification, stakeholder confidence	Statistical analysis of ESG risk assessments, correlation studies	Organizations using AI for ESG risk analysis saw 8–14% higher profitability.
Field	2019	Carbon footprint, supply chain efficiency, energy usage	AI-powered supply chain optimization models	AI reduced corporate carbon footprints by 22% in energy-intensive industries.
Ginevicius et al.	2021	Greenhouse gas emissions, logistics data, compliance timelines	Machine learning models for emission hotspot prediction	Achieved 30% faster decarbonization in logistics networks using AI-driven compliance tools.
Brem et al.	2020	Employee retention, compliance speed, SDG alignment	Longitudinal studies, surveys on AI adoption	AI adoption linked to 19% higher employee retention and 25% faster regulatory compliance.

Authors	Year	Variables	Methods	Findings
de Sousa Jabbour et al.	2017	Reputational risk, operational costs, ESG disclosure rates	Case studies on multinational banks, cost-benefit analysis	AI-driven ESG disclosures reduced reputational risks by 40% and operational costs by 15%.
Karcher & Jochem	2015	Production costs, ESG compliance metrics, lifecycle emissions	Lifecycle assessment (LCA) with AI integration	Reduced production costs by 12% while improving ESG compliance.
Lahouel et al.	2021	Endogeneity bias, ESG spending, profitability	Instrumental variable approaches, econometric modeling	Correcting endogeneity reversed prior negative ESG-profitability correlations.
Ben Lahouel et al.	2019	ROA, ownership structures, international legitimacy	Comparative analysis of foreign vs. domestic banks	Foreign-owned banks achieved 9% higher ROA from ESG investments.
Moneva et al.	2020	ESG reporting accuracy, regulatory compliance, audit costs	Pre/post-EU taxonomy analysis, AI-driven audit tools	Post-2018, EU taxonomy adoption increased ESG reporting accuracy by 35%.
Boubakri et al.	2020	Liquidity coverage ratios, cross-border operations, AI-ESG frameworks	Analysis of 2,300 European banks, regression models	Foreign subsidiaries with AI-ESG frameworks outperformed peers by 14% in liquidity during downturns.
Houston et al.	2010	Credit risk prediction accuracy, ESG-linked default probabilities	Machine learning vs. linear regression comparisons	Machine learning improved credit risk prediction accuracy by 27%.
Bilgin et al.	2021	Systemic risk volatility, ESG scores, capital adequacy	Crisis-period volatility analysis, AI-driven scenario planning	High-ESG banks had 33% lower volatility during 2020–2023 crises.
Anderson	2023	Risk-adjusted returns, ESG portfolio performance, asset valuation	AI-driven portfolio optimization, machine learning asset screening	ESG-aligned portfolios using AI achieved 18% higher risk-adjusted returns.
Cunha et al.	2021	Portfolio rebalancing latency, ESG news sentiment, market responsiveness	Real-time sentiment analysis, latency tracking in asset management	AI reduced portfolio rebalancing latency by 65% through ESG news analysis.

Source: Data processing by authors (2025)

Combining environmental, social, and governance (ESG) approaches with artificial intelligence (AI) and innovation in finance presents a tremendous opportunity for the banking industry to improve efficiency, reduce risks, and drive sustainable growth. Numerous studies consistently show that AI-driven ESG frameworks increase operational efficiency, reduce compliance costs, and strengthen financial

stability. Banks that use AI for their ESG efforts tend to have higher profits, greater risk diversification, and more remarkable systemic stability during economic crises. Furthermore, these methods promote transparency, regulatory compliance, and stakeholder trust while supporting sustainability objectives such as reducing carbon emissions and ensuring ethical governance.

However, successful implementation requires overcoming challenges such as data biases, fundamental problems in ESG performance assessments, and the need for uniform metrics. Various studies and empirical analyses highlight that combining ESG, AI, and financial strategies offers a competitive advantage. It represents an essential path for banks to align their profitability with global sustainability objectives in the face of growing environmental and economic challenges.

3 Scientific research methodology

This study is based on a qualitative methodology, which uses a case study approach to analyze the integration of environmental, social, and governance (ESG) sustainability strategies and artificial intelligence (AI) in the banking industry. The methodology is designed to provide an in-depth and structured analysis of the impact of these strategies on banking performance and risk management. In this context, three major banks are analyzed: Nova Ljubljanska Banka (NLB) in Slovenia, Erste Group Bank AG in Austria, and Bank of Valletta (BOV) in Malta. Data for these banks are collected from reliable sources, including official reports, institutional documents, and other relevant materials. Each case study is carefully treated, focusing on implementing ESG and AI in the banking sector and their impact on financial performance and operational transparency.

A core methodology element uses a benchmarking matrix to assess each bank's ESG and AI performance. This matrix enables the analysis of key factors such as operational efficiency, impact on sustainable investments, increased transparency, and benefits in risk management. Using this benchmarking approach, the study identifies best practices and highlights how ESG and AI help improve financial and non-financial indicators. To provide a deeper understanding of the impact of ESG and AI, the methodology also includes a thematic analysis of different implementation models of these strategies in the banking industry. Through this analysis, the study examines the mechanisms of ESG and AI adoption, assessing

their effectiveness in improving overall banking performance and creating competitive advantages.

Another critical component is the development of a matrix of priorities and strategies for integrating ESG and AI. This matrix categorizes key measures and initiatives based on their importance for sustainable development and strategic benefits for banks. Priorities about their impact on risk management, technological innovation, and increased financial sustainability are assessed. In conclusion, this methodology enables an in-depth and comprehensive analysis of the effects of ESG and AI on banking performance. Combining comparative analysis, case studies, and thematic approaches, the study provides a clear overview of the benefits and challenges of implementing these strategies, highlighting best practices and opportunities for improvement in the banking sector.

4 Case study analysis

Nova Ljubljanska Banka (NLB), Slovenia's most extensive banking institution and one of the financial leaders in Southeastern Europe, has taken necessary steps to integrate ESG strategies and artificial intelligence (AI). To improve risk management, financial performance, and operational transparency, the bank has invested in advanced technologies and developed sustainable products that promote responsible financial practices. One of the key aspects of NLB's transformation is the optimization of risk assessment through AI, which enables the bank to analyze financial and environmental data more accurately, improving lending decision-making and reducing non-performing loans. This process has been supported by a more comprehensive approach to sustainability, where the development of green financing products has played an essential role in attracting investments oriented towards renewable energy and ecological projects. In addition to these initiatives, NLB has improved transparency and financial reporting through the analysis of ESG data. AI has facilitated the monitoring of its investments' environmental and social impact, ensuring a deeper integration of ESG factors into banking strategies. This approach has helped create a more reliable reporting model and improved stakeholder communication.

Another important step has been automating processes to increase efficiency, which has reduced operational time and costs. AI technology has brought significant improvements in advanced risk analysis, customer service optimization, and market monitoring, increasing the bank's flexibility and responsiveness to new challenges in the financial sector. Through these strategies, NLB has created a sustainable and innovative banking management model, reinforcing its position as a leading institution in the region's sustainable finance field.

Table 2: Key Results of ESG and AI Implementation at NLB

Aspect	*Results at NLB*	*Impact*
Operational efficiency	*Cost reduction through process automation with AI (10-15%).*	*Improved productivity and more efficient allocation of resources.*
Increasing sustainable investments	*20% increase in green financing portfolio.*	*Support for the transition to a greener economy.*
Transparency and reporting	*Improvement in the quality of ESG reporting and integration with international standards.*	*Increased credibility among investors and stakeholders.*
Risk management	*AI has reduced the rate of non-performing loans by 8%, improving the quality of the loan portfolio, achieving higher financial stability, and reducing loss risks.*	*Higher financial stability and reduced risk of loss.*
Incorporating ESG factors into decision-making	*80% of new corporate loans go through an ESG filter for sustainability assessment.*	*Improving the sustainability of long-term investments.*

Source: Prepared by the authors based on NLB data and ESG reports (2025)

Table 2 summarizes in a clear and structured way the impact of ESG and AI implementation on the performance of Nova Ljubljanska Banka (NLB), providing important insight into the transformation of the banking sector through technology and sustainability. One of its most valuable aspects is the demonstration of an integrated approach, where AI not only improves risk management and operational efficiency but also helps to increase sustainable investments and the inclusion of ESG factors in decision-making. The improvement of transparency and trust in the market, as well as the positive impact on the financing of green projects, shows that technology can be a key catalyst for developing a more responsible banking model. This case study confirms the success of NLB. It provides an applicable model for financial institutions that aim to balance technological innovation with sustainability objectives, creating a more resilient and future-oriented financial sector.

Nova Ljubljanska Banka has demonstrated an advanced approach to risk management and improved financial performance by integrating AI and ESG. The results show a significant increase in operational efficiency and a substantial reduction in the risk of non-performing loans. Overall, this case study shows how a traditional financial institution can adopt advanced technologies to improve financial sustainability, creating an innovative model for the banking sector in the region.

Erste Group is one of the largest financial institutions in Central and Eastern Europe, with a strong focus on integrating sustainability (ESG) strategies and artificial intelligence (AI) to improve risk management, strategic decision-making, and commitment to social and environmental responsibility. The bank has taken concrete steps to analyze ESG data more efficiently through AI, enabling the identification of sustainable investment opportunities and reducing exposure to activities with negative impacts. The use of advanced algorithms has facilitated the assessment of the environmental impact of projects, helping to develop a green financing portfolio.

One of Erste Group's key strategies has been to create financial products that promote sustainable practices, such as green loans with preferential interest rates for individuals and businesses investing in renewable energy or projects with a positive environmental impact. These schemes have helped increase the percentage of loans dedicated to sustainable projects and strengthen the bank's position as a leader in responsible financing. Furthermore, improved governance and increased transparency in ESG reporting have led to greater investor engagement, creating a more conducive environment for sustainable capital. In terms of risk management, Erste Group has implemented AI analysis mechanisms to improve the control of financial and environmental risks. These technologies have facilitated the early detection of potential risk factors and have helped to design preventive strategies to maintain the bank's financial stability. These initiatives have brought significant improvements in operational efficiency and loan portfolio management and increased positive impact on the community.

Table 3: Results and Impact of ESG and AI Strategies at Erste Group

Aspect	*Results at Erste Group*	*Impact*
ESG data analysis	*30% improvement in identifying sustainable investment opportunities*	*Increasing accuracy in strategic decision-making for responsible investments*
Sustainable financing	*Development of green credit schemes with preferential interest*	*Encouraging sustainable practices in businesses and individuals*
Improving governance	*Increasing investor engagement in ESG*	*Strengthening transparency and trust in financial markets*
Risk reduction	*Using AI to improve risk analysis and control*	*Stabilizing the loan portfolio and minimizing exposure to environmental risks*

Source: Prepared by the authors based on Erste Group data and ESG reports (2025)

Table 3 provides a clear overview of the impact of ESG and AI strategies at Erste Group, highlighting the transformation of financial institutions through innovation and sustainability. A key aspect of this analysis is the advanced use of AI in improving risk analysis and identifying sustainable investment opportunities, enabling a more strategic and informed approach to capital management. In addition, green credit schemes with preferential terms not only encourage responsible behavior among businesses and individuals but also contribute to the transition to a more sustainable economy. Improving governance and increasing investor engagement in ESG strengthens transparency and positively impacts the stability of financial markets. This case study is a valuable example for financial institutions that aim to integrate ESG and AI effectively, balancing technological innovation with social and environmental responsibility to ensure long-term sustainable development. These results show that Erste Group has effectively balanced technological innovation and commitment to sustainability, improving financial performance and the overall impact on society and the environment.

The third case study in this paper is the Bank of Valletta (BOV), which, as the largest financial institution in Malta, has taken significant steps towards incorporating sustainability into its business strategy. By integrating artificial intelligence (AI) and environmental and social governance (ESG) criteria, BOV aims to improve risk management and compliance with international standards and promote the financing of green projects. One of BOV's key innovations is using AI to monitor ESG performance and ensure compliance with global regulatory standards. Through advanced data analytics, the bank has managed to standardize ESG reporting, improving the transparency and reliability of information for investors and

stakeholders. Furthermore, AI has facilitated automated reporting and auditing processes, reducing costs and errors.

As part of its commitment to sustainability, BOV has invested significantly in renewable energy financing, orienting 25% of its loan portfolio towards green projects. This step aims to support businesses and individuals transitioning to a low-carbon economy. Improving governance and compliance with international standards has also been a priority for the bank. Through AI technologies, BOV has increased the efficiency of internal processes, strengthened risk management controls, and reduced exposure to financial and reputational risks.

Table 4: Results and Impact of ESG and AI Integration in BOV

Aspect	*Results in BOV*	*Impact*
ESG monitoring	*Increasing clear and standardized ESG reporting*	*Greater transparency and increased credibility*
Supporting green projects	*25% of the financing portfolio directed to renewable energy*	*Supporting the transition to a green economy*
Improving governance	*Increased compliance with international standards*	*Reducing financial and reputational risks*
AI technology	*Process automation to reduce errors and costs*	*Increased operational efficiency and cost savings*

Source: Prepared by the authors based on data from the Bank of Valletta and ESG reports (2025)

Table 4 explains the impact of ESG and AI at the Bank of Valletta (BOV), showing how technology and sustainable practices can strengthen transparency, governance, and operational efficiency. A crucial aspect is the bank's strategic orientation towards financing renewable energy, with 25% of its portfolio demonstrating a strong commitment to a green economy. This helps reduce its environmental footprint and creates opportunities for sustainable financial growth. Using AI to automate processes reduces errors and costs and improves decision-making, bringing greater efficiency and compliance with international standards. This case study provides a valuable model for other financial institutions seeking to integrate ESG and AI strategically, maximizing economic and social benefits. This case study demonstrates how a large regional bank like BOV can use AI and ESG to transform its operations, helping to create a more sustainable and responsive financial sector to environmental and social challenges.

5 Comparative matrix results and thematic analysis

The thematic analysis of three banks, NLB Bank, Erste Group, and Bank of Valletta, provides a clear overview of their strategic approaches to sustainability and green finance. It focuses on five key criteria: sustainability strategies, green financial products, applied technologies, key challenges, and key benefits. This analysis explains how these financial institutions integrate ESG (Environmental, Social, and Governance) principles into their operations and impact the financial market through innovation and compliance with sustainability regulations.

Table 5: Results of the comparative matrix between banks: NLB, Erste Group, and Bank of Valletta

Criteria	*NLB Bank*	*Erste Group*	*Bank of Valletta*
Country	*Slovenia*	*Austria*	*Malta*
Sustainability strategy	*Focus on green finance and sustainable development*	*Comprehensive approach to ESG and green investments*	*Implementation of green financial strategies*
Green financial products	*Energy efficiency and electric vehicle loans*	*Green bonds and loans for sustainable enterprises*	*Renewable energy financing scheme*
Applied technologies	*Digitalization of banking services to reduce the ecological footprint*	*Advanced digital platforms for sustainable investment management*	*Automating banking processes to reduce paper usage*
The main challenge	*Increasing customer awareness of sustainable finance*	*Full integration of ESG at all operational levels*	*Compliance with European regulations on sustainability*
Main benefits	*Increasing financial stability and reputation*	*Rritja e vlerës për aksionarët dhe partnerët strategjikë*	*Improving customer trust and competitive advantage*

Source: Prepared by the authors based on data from NLB Bank, Erste Group, and Bank of Valletta.

This matrix provides an in-depth and comparative analysis of three major banks' sustainability strategies and practices: NLB Bank, Erste Group, and Bank of Valletta. It focuses on five key areas: sustainability strategy, green financial products, applied technologies, key challenges, and key benefits. This comparison helps visualize each bank's approach to sustainable finance and green innovations.

NLB Bank has a structured approach to integrating sustainability into its operations, focusing on financing projects with low environmental impact. The bank has issued green bonds to support investments in energy efficiency and renewable energy, prioritizing the reduction of ecological impact through digitalizing services.

However, NLB Bank's main challenge is to raise customer awareness of the importance of green finance and its effect on the long-term economy.

On the other hand, Erste Group has a comprehensive approach to ESG, incorporating it at all levels of its banking and investment operations. The bank has created green investment funds and an innovative digital platform, "George", which allows clients to manage their investments in line with sustainability principles. Erste Group is also involved in initiatives such as the European Commission's Green Consumption Pledge, demonstrating its commitment to a sustainable financial transformation. Its main challenge lies in integrating ESG at all operational levels, a complex process that requires clear regulations and the involvement of all stakeholders.

Bank of Valletta, located in a smaller market like Malta, focuses on renewable energy financing schemes to support businesses and individuals transitioning to clean energy. It has adopted green financial strategies and implemented automation of banking processes to reduce paper usage and increase operational efficiency. However, a key challenge for the Bank of Valletta remains compliance with European regulations on sustainability, which requires significant resources to implement and monitor the new standards. The main benefits of these strategies include increased financial stability and reputation for NLB Bank, increased value for shareholders and strategic partners for Erste Group, and competitive advantage and improved customer trust for Bank of Valletta. This comparison shows that despite the differences in the strategies implemented, all banks are prioritizing innovation, digitalization, and sustainable finance, improving their competitiveness in the international financial market.

The thematic network diagram presents a comparative analysis of sustainability strategies among three major banks: NLB Bank, Erste Group, and Bank of Valletta. The study is structured at three hierarchical levels: global theme, organizational themes, and specific themes, enabling a clear understanding of how each bank integrates sustainability into its operations. At the highest level, the global theme focuses on sustainable finance and green banking, underlining the commitment of financial institutions to support sustainable development, reduce ecological impact, and respect regulatory frameworks for green finance. Within this framework, five organizational themes have been identified that represent the main dimensions of

bank sustainability strategies: sustainability strategy, green financial products, applied technologies, key challenges, and key benefits. Each bank follows different approaches within these themes.

NLB Bank focuses on financing renewable energy and electric vehicles, using digitalized services to reduce ecological impact, but faces the challenge of raising customer awareness of sustainable finance.

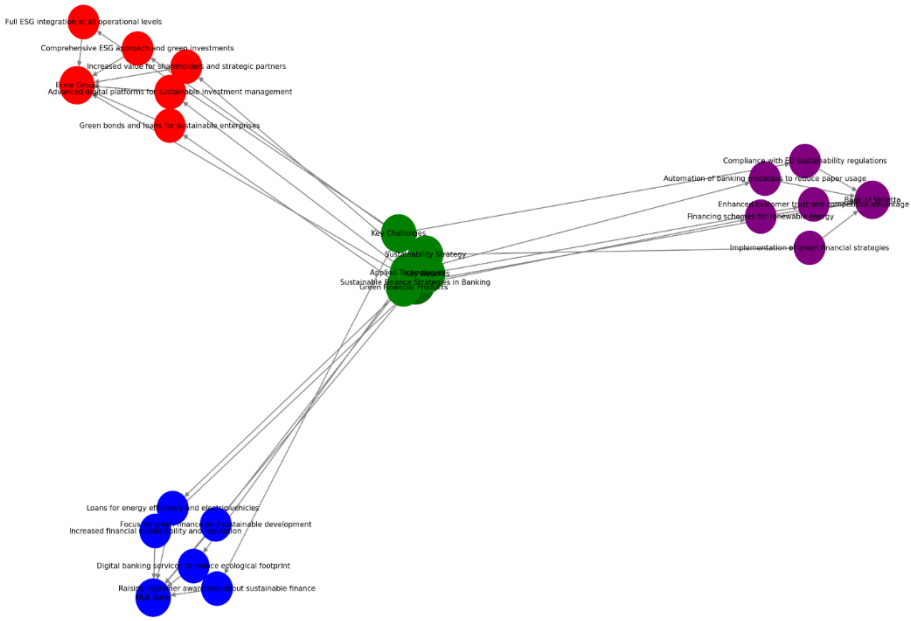

Figure 1: Thematic Network Diagram: Comparative Analysis of Sustainability Strategies in NLB Bank, Erste Group, and Bank of Valletta
Source: The authors created the source using NVivo, based on data from official documents and annual reports of NLB Bank, Erste Group, and Bank of Valletta (2025).

Erste Group has a comprehensive approach to ESG, offering green bonds and digital platforms for sustainable investment management. However, its main challenge remains the full integration of ESG at all operational levels. Bank of Valletta has embraced green financing strategies for renewable energy and process automation to reduce paper use while facing regulatory challenges within the EU framework. Despite their differences, all three banks share common goals, such as sustainable development, regulatory compliance, and improving reputation and

financial value. The thematic network analysis helps to understand the connections between these strategies, providing a clear framework for interpreting banks' efforts toward a more sustainable economic system.

6 Results of the ESG priorities and strategies matrix and ai integration in the banking industry

Banks face new challenges and opportunities in risk management, digitalization, and compliance with ESG (Environmental, Social, and Governance) regulations in an increasingly sustainability-oriented and technologically innovative financial environment. In this context, artificial intelligence (AI) is becoming a key tool to increase efficiency, analyze big data, and optimize decision-making aligned with sustainability objectives. Based on the analysis of three major banks, NLB Bank, Erste Group, and Bank of Valletta, this matrix categorizes and assesses the main priorities and strategies for integrating ESG and AI in the banking sector. This analysis aims to identify the most important measures and initiatives that impact these institutions' sustainable development, risk management, and competitive advantages. The integrated strategies reflect the bank's commitment to sustainable finance, digitalization, and innovation to ensure a stronger position in the global market.

Table 6: Matrix of Priorities and Strategies for Integration of ESG and AI in the Banking Industry

Criteria	*NLB Bank*	*Erste Group*	*Bank of Valletta*
ESG integration	*Issuing green bonds and financing sustainable projects*	*ESG is integrated into all levels of operations*	*Compliance with European sustainability regulations*
AI implementation	*Digitalization of banking services to reduce ecological impact*	*"George" platform for sustainable investment management*	*Automate processes to reduce paper usage*
Risk management	*Improving risk assessment models for sustainable finance*	*Incorporating ESG indicators into risk assessment*	*Adaptation of monitoring mechanisms for the implementation of regulations*
Technological innovation	*Improving digital platforms for green loans*	*Investing in artificial intelligence for ESG analysis*	*Implementation of sustainability reporting technologies*
Increasing financial sustainability	*Diversifying your green investment portfolio*	*Incorporating ESG strategies into financial decision-making*	*Increasing transparency and stakeholder involvement*

Source: Prepared by the authors based on data from NLB Bank, Erste Group and Bank of Valletta (2025).

This matrix assesses the key initiatives of NLB Bank, Erste Group, and Bank of Valletta about sustainable development, focusing on ESG integration, implementing artificial intelligence, risk management, technological innovation, and increasing financial resilience. Its value lies in highlighting the strategic approaches of these banks, showing how sustainability factors affect long-term performance and financial stability. Banks incorporating ESG into their operations, such as Erste Group, have a competitive advantage as they adapt more quickly to international regulations and investor pressure for transparency and social responsibility. Artificial intelligence, as in the case of Erste Group's "George" platform or the automation of processes by the Bank of Valletta, shows that technological innovation is an essential tool for increasing efficiency and reducing environmental impact. Improving risk management models by incorporating ESG indicators, as Erste Group has done, helps reduce exposure to external factors and strengthens the financial sector's stability. Enhancing financial sustainability through green investment strategies and financial transparency, as in the case of the Bank of Valletta, increases market and investor confidence. This matrix shows that incorporating sustainability into banking strategies is an ethical commitment and a key factor for financial institutions' competitiveness and long-term success.

Figure 2: Key Terms in ESG and AI Integration Strategies in Banking
Source: The authors created the source using NVivo, based on data from ESG and AI Integration Priorities and Strategies Matrix in the Banking Industry (2025).

The keyword chart overviews the most essential terms identified in the banking industry's ESG and AI Integration Priorities and Strategies Matrix. This chart focuses on key strategic areas such as financial sustainability, risk management,

technological innovation, and regulatory compliance. It highlights how banks adapt these elements to improve their long-term performance and impact. The size of each word reflects the importance and frequency of its use in the analysis of integrated strategies. More prominent words indicate terms significantly impacting banking decision-making, while smaller words reflect supporting factors that help achieve sustainability and innovation objectives. This chart provides a quick and intuitive way to understand the key areas of development in the banking sector.

An important aspect that this graph highlights is the strategic scope of banking priorities. For example, suppose terms like "risk management" and "technological innovation" appear in large numbers. In that case, this indicates that banks consider these elements as key pillars for their stability and competitiveness in the market. Likewise, "sustainability" and "ESG" suggest a strong orientation towards green financing policies and compliance with European regulations. This graph can also help identify strategic gaps by comparing keywords with industry objectives. If some critical terms are missing or are underrepresented, this may signal the need for a greater focus on specific aspects, such as further digitalization or strengthening sustainability policies.

7 Conclusions and recommendations

Based on the analysis of case studies and a comparative matrix on the integration of ESG and AI in the banking industry, the study draws several key conclusions regarding the importance of these strategies in strengthening financial sustainability and innovation. The findings show that banks are approaching ESG not only as a regulatory obligation but as a long-term strategy to ensure competitiveness and operational sustainability. In this regard, NLB Bank has shown a strong focus on financing green projects and improving risk assessment models; Erste Group has demonstrated deep integration of ESG at all levels of operations and significant investments in artificial intelligence. In contrast, the Bank of Valletta has fully complied with European regulations and focused on automating processes to reduce environmental impact. The strategic priority matrix shows that the key elements driving the success of these banks are the diversification of the portfolio of sustainable investments, the adoption of advanced risk management mechanisms, and the application of AI to optimize operations and market analysis.

In this context, it is clear that there is a direct link between the degree of technological advancement and the improvement of ESG performance, underlining the need for an integrated approach between sustainability management and digital development. The findings also suggest that one of the main challenges in this process is the alignment of investments in AI with sustainability reporting requirements, seeking innovative solutions that can support transparency and regulatory efficiency. Another important aspect derived from this study is the impact of these strategies on increasing shareholder value and improving stakeholder perception, reflecting the importance of a proactive commitment to including ESG as part of the banking strategy.

Based on these conclusions, the study recommends that banks implement an operational model oriented towards advanced automation to reduce costs and increase the efficiency of ESG services. It is also essential that they invest in integrated artificial intelligence systems that facilitate the decision-making process and ensure alignment with sustainability regulations and international standards. Furthermore, banks should develop more sophisticated mechanisms for assessing ESG impact and include more environmental and social indicators in risk analyses. In terms of transparency and governance, this study suggests strengthening reporting mechanisms to increase investor confidence and facilitate adaptation to the new European Union norms on the sustainability taxonomy.

From a practical perspective, banks can benefit from adopting artificial intelligence models to analyze real-time data on ESG impacts and personalize financial offerings according to customer needs. Strategic partnerships with technology companies and academic institutions can also create new methodologies for integrating ESG into risk management and strategic decision-making. This study also suggests that regulators encourage the development of harmonized standards for ESG reporting and facilitate the creation of common data platforms for banks, thus helping to facilitate the implementation of sustainability strategies.

In conclusion, this study highlights that integrating ESG and AI in the banking industry is a trend and a strategic need to enhance the sector's long-term sustainability and competitiveness. Banks that adopt an advanced approach to these elements will be better positioned to face market challenges and capitalize on digital transformation and sustainability opportunities.

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THE LEGAL IMPLICATIONS OF AI IN CORPORATE GOVERNANCE FROM DIRECTORS' RESPONSIBILITIES TO REGULATORY EVOLUTION

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Integrating artificial intelligence (AI) into corporate governance presents a dual challenge. On one hand, it offers significant opportunities for enhanced efficiency and strategic decision-making. On the other hand, it introduces complex legal, ethical, and financial challenges, particularly concerning directors' fiduciary duties. As AI transforms business processes, corporate leaders must ensure compliance, transparency, and accountability, particularly about shareholders, investors, and business partners. A significant element of AI governance is the regulatory leadership demonstrated by the European Union, with the AI Act providing the first comprehensive legal framework for AI adoption. In an era of political uncertainty, stakeholders strive to balance fostering AI-driven innovation and maintaining accountability. Directors must align corporate governance structures with these regulations to ensure AI's legal and ethical use. Financial reporting has a pivotal role in disclosing AI-related risks to investors and regulatory bodies, thereby strengthening corporate transparency and accountability. Corporate leadership is thus responsible for establishing effective oversight mechanisms that mitigate risks while promoting responsible AI-driven innovation. By enhancing governance structures and ensuring comprehensive AI supervision, directors will uphold corporate integrity, sustain investor confidence, and successfully navigate the evolving regulatory landscape.

Keywords:
artificial intelligence, corporate governance, shareholder risks, responsibility of directors, regulatory compliance, fiduciary duties, AI regulation.

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1 Introduction

Integrating artificial intelligence (AI) into various aspects of life is a growing phenomenon with significant implications for economic and regulatory frameworks (Hacker, 2021). Developing an appropriate legal framework is crucial to ensuring the safe utilization of all forms of AI. Such a framework should also support advancing new technologies to enhance effectiveness and efficiency across various sectors (Primec, 2020).

The European Union (EU) was the first to regulate, with several innovations in this area being proposed in recent years. The most significant changes have been triggered by the AI Act (Regulation 2024/1689), the world's first comprehensive legal framework for the regulation of AI, with a focus on the risks associated with AI and the EU's leading role in this field. A new Directive on Product Liability (Directive 2024/2853) for defective products was adopted. It entered into force on December 8, 2024, and replaced the almost forty years old previous directive. However, at the beginning of 2025, the European Commission withdrew its intention to propose an AI liability directive (Proposal for a Directive 2022/496). This proposal had been under consideration for a considerable time.

Given its direct impact on fundamental corporate processes and accountability, analyzing AI from a corporate governance and law standpoint is imperative.

Integrating AI presents significant challenges for corporate decision-makers who are often tasked with determining where and how AI systems should be implemented. These decisions can substantially impact the company's costs, risks, and growth opportunities. This highlights two essential questions that must be addressed: **Is it the board of directors' responsibility to implement new technologies?** Conversely, **could prematurely introducing new technology without sufficient information be considered irresponsible behavior?** In this context, finding the right balance is crucial: **insufficient reliance on AI may result in inefficiency while excessive reliance may expose the company to significant risks** (Ahern, 2024).

The potential advantages of AI are considerable, particularly in the context of risk management and improving business processes within corporate governance. These advantages are primarily attributed to the ability of computer algorithms to improve over time, as evidenced by the large volumes of data they process, which play a crucial role in enhancing their learning capabilities. While data processing is essential for improving AI systems, however, it raises concerns regarding data protection and privacy (Primec, Pastirk & Perko, 2024; Boillet, 2018). Consequently, AI systems can potentially become more effective in managing corporate risks. Such systems can develop sophisticated tools that enhance an organization's capacity to monitor key areas, such as regulatory compliance and corporate governance (Boillet, 2018).

2 Methodology

The present paper offers a legal analysis of the liability of directors in companies concerning the use of AI. It should be noted that both corporate governance and AI are complex and interdisciplinary fields. By contrast, the purpose and focus of the present paper are significantly narrower in scope because it primarily concentrates on the specific issue of directors' liability in connection with the use of AI.

The first part of the paper predominantly employs the descriptive method which provides readers with a broader understanding of the research subject. This section is structured thematically, addressing key concepts essential for understanding the topic. The nomotechnical analysis and analytical method are also applied to present the relevant legislative framework.

In the continuance of the research, directors' liability for using AI is primarily analyzed through the nomotechnical analysis, the legal-logical method, and the descriptive method. The combination of these methods is intended to provide a comprehensive presentation of the legal framework and to emphasize the key challenges that directors encounter when implementing AI in business processes.

3 Theoretical background

Companies must develop a comprehensive corporate governance framework to harness the potential of AI while managing the risks described above. To understand this role, it is necessary to identify the fundamental principles of corporate governance.

Corporate governance can be defined as a constitutive element that guides and shapes the activities of economic entities. A multitude of definitions of corporate governance can be found in the literature. Berle and Means emphasized the separation of ownership and control, whereby owners often entrust management to managers (Bratina & Pašić, 2010). Similarly, Štiblar (2010) highlighted the conflict of interest between managers and owners as a key feature of corporate governance. In contrast, Trstenjak (2003) sees corporate governance as a broader framework encompassing forms of governance and control, especially in public limited companies. Minow & Monks (2001) and Gregorič (2003) define corporate governance as a network of relationships between a company's bodies and stakeholders, influencing corporate performance and the capital market. According to Tičar (2016), corporate governance is the establishment of control mechanisms to ensure investor returns while safeguarding the company's long-term stability. However, Bohinc & Bratina (2005) have highlighted that the term 'corporate governance' is most often used about companies, despite the Slovenian legal order not recognizing a specific legal form of a corporation. Instead, it speaks of commercial companies.

While the definitions of corporate governance vary in their respective emphases, they are unified by the necessity of establishing mechanisms that facilitate effective decision-making, risk management, and the protection of stakeholders' interests.

Thus, corporate governance contributes to enhancing economic efficiency and fostering societal growth.

A comprehensive corporate governance framework is crucial in ensuring the transparent, accountable, and secure use of AI in companies. Such a framework should incorporate strategies that promote the responsible deployment of AI while establishing risk management measures within internal company systems (Daidai &

Tamine, 2023). The effective integration of AI in a business environment has the potential to optimize decision-making processes and thus create added value. Corporate boards must possess a comprehensive understanding of AI systems because they play a pivotal role in establishing and overseeing mechanisms that ensure compliance with legal regulations, ethical principles, and security standards. In doing so, they contribute to risk mitigation while promoting the responsible use of AI within the company (Gregory, 2023).

All of this is particularly important since the management bodies of a company (especially the management board or executive management) are responsible for managing the company's affairs in its internal relations and representing it in external relations. In addition to these duties, management bodies are also tasked with performing entrepreneurial leadership functions which include managing the company, defining business policies, and making fundamental organizational and strategic decisions related to risk management. The duties of directors are precisely defined by legislation. In the Slovenian legal system, the Companies Act regulates directors' positions and responsibilities (Zakon o gospodarskih družbah (ZGD-1), 2006).

As members of the management or supervisory body, directors and supervisory board members have a fundamental duty under corporate law to manage and oversee the company on behalf of the company with the diligence of a conscientious and honest businessperson. This duty also entails fulfilling contractual obligations towards the company's creditors and considering the legitimate interests of other entitled stakeholders (Bratina, 2024). The ZGD-1 defines the duty of conduct and the standard of care required of members of the management or supervisory body, stipulating that in the event of a breach of this duty, they may be held liable for damages to the company (Cepec & Kovač, 2019).

Two fiduciary duties are particularly relevant in this regard: **the duty of loyalty** and **the duty of care (Podgorelec, 2015).** Both duties are essential in ensuring that management bodies approach the adoption of AI with diligence, foresight, and accountability, thereby minimizing potential risks while maximizing the technology's potential benefits (Ahern, 2024). Kocbek emphasizes that when analyzing the liability of management or supervisory body members, a significant question arises: how to distinguish between a poor business decision and a breach

of the duty of care. It is essential to recognize that business decisions not only present opportunities for success (profit) but also inherently involve a certain degree of risk. The management is not only expected to seek business opportunities for the company but also to have the courage to make decisions — even if they involve a degree of risk (Kocbek et al., 2014, p. 81).

The business judgment rule has been firmly established and widely recognized in Anglo-American law. Although the Slovenian ZGD-1 does not explicitly codify the business judgment rule, it has nevertheless been adopted through case law (Bratina, 2024). Bratina stresses that a business decision that ultimately proves incorrect does not automatically constitute a breach of the duty of care. When assessing liability, it is imperative to consider the business judgment rule regarding damages and criminal matters.

4 Discussion

Understanding new technology systems, including AI, is a complex area studied by different scientific disciplines. Presently, the AI Act is this domain's most comprehensive legislative treatment. However, European and Slovenian legislation lacks explicit articulation of the obligations of directors and supervisors to ensure the responsible use of AI systems.

Boillet stresses that corporate leadership should comprehensively understand how AI technologies are applied within the organization and its external environment. They must establish appropriate structures to address ethical concerns and remain cognizant of the challenges posed by algorithmic bias (European Union Agency for Fundamental Rights, 2022; Baer, 2019). Furthermore, they must stay informed about emerging frameworks, policies, and legislation to ensure their company balances algorithmic transparency and accountability appropriately.

As previously stated, there is an absence of specific legal regulations that govern the obligations and responsibilities of governing bodies regarding the utilization of AI technology. Consequently, it becomes imperative to consider the legal interpretation and analogy of existing legal provisions when addressing these issues. In general terms, the liability of directors can be attributed to their fiduciary duty, which encompasses the imperative of ensuring the lawful conduct of business. The

obligations of directors and their liability about the use of AI technology are not explicitly regulated by legislation. As a result, addressing these issues relies on legal interpretation and applying existing statutory provisions by analogy. The obligations of management bodies regarding AI are primarily determined by each company's circumstances in specific cases. Various factors are considered when assessing the implementation of AI systems in a corporate context. These include the nature of the company itself (such as its size, sector of activity, and technological infrastructure), the level of technological development, the risks associated with using AI systems, and the potential of alternative technologies that could replace applied AI. Given these circumstances, the rules of due diligence and general principles of corporate law will apply (Schalast, n.d.).

Directors' duties are not worded to narrowly prescribe the actions that must be taken to comply with them. As Ahern (2024) emphasizes, the flexibility inherent in directors' duties is designed to accommodate dynamic business developments, including technological advancements, such as AI. Consequently, while AI's role may influence the context in which directors' duties are applied, it should not shift their overarching content. Nevertheless, the board must address the following questions. Boards must address a range of complex decisions when considering AI's integration in areas, such as strategy, operations, oversight, compliance, and reporting. Corporate law places significant responsibility on individual and collective directors, which means that boards cannot simply delegate AI-related matters to a director or committee presumed to possess expertise in this field (Ahern, 2024).

When a company employs AI systems that impact its operations and the associated risks significantly, members of the management bodies are expected to act following the standard of care exercised by a diligent and prudent manager. The management enjoys considerable discretion in decision-making (Schulte, 2024). However, decisions must be made based on appropriate information and in the company's best interest. This implies that management bodies must consider the company's interests from the perspective of the consequences their actions may have. It is important to emphasize that a company has distinct interests, which may differ from the interests of its shareholders. Acting in the best interest of the company means that the conduct of management bodies should be aimed at enhancing the company's position and its relationships with third parties, ultimately maximizing the value of

the company's assets and achieving the highest possible return on those assets (Kocbek et al., 2014).

A prudent approach would ensure adequate oversight of AI systems while adopting predetermined procedures and familiarizing AI systems with rules resembling the instructions typically given to employees (Schulte, 2024).

The board is responsible for establishing the organization's AI risk appetite and providing high-level scrutiny over its AI strategy. In addition, the board should ensure that AI is used and deployed responsibly and that all users of AI tools receive appropriate training. It is also recommended that an approval chain be established for each AI use case, thus allowing for proper evaluation of the risks and opportunities and the appropriate application of guardrails (Sharma, 2025).

5 Conclusion

The article has outlined many open questions related to AI that have emerged in the context of the rapid development of this new technology in recent years. Comprehending these issues is complex, requiring a simultaneous understanding of legal frameworks and AI systems. Mainly through adopting the AI Act, the EU has been the first to introduce comprehensive regulation in this area. Nonetheless, the new regulation has raised several questions regarding its adequacy and effectiveness.

Considering the potential risks associated with AI technology, corporate management is expected to implement procedures to prevent or minimize risks that could impede the adoption of harmful AI systems (e.g., algorithmic bias). Establishing adequate internal control and compliance systems within companies would prove the directors fulfill their duty of care.

In conclusion, as was previously emphasized, directors and supervisory board members must manage the company with the duty of care of a prudent and diligent manager while acting in the company's best interests. Given the growing role of AI, AI oversight must be integrated into the broader risk management framework. To do so, company leaders must understand the impact of AI on the company's strategic direction, regulatory compliance, and ethical considerations. Furthermore, it is

incumbent upon them to establish appropriate precautionary mechanisms to manage the associated risks effectively.

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THE HUMAN SIDE OF DIGITALIZATION: HRM'S ROLE IN FOSTERING DIGITAL WELL-BEING

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Digital technologies have revolutionized workplace operations, enhancing communication, efficiency, and access to information. However, they also introduce significant challenges, including digital overload, constant connectivity, and blurred work-life boundaries, which can negatively affect digital well-being and organizational productivity. This study explores the strategic role of Human Resource Management (HRM) in addressing these challenges through a qualitative synthesis of existing literature. Special attention is given to integrating digital well-being initiatives within Environmental, Social, and Governance (ESG) frameworks and leveraging emerging technologies such as artificial intelligence (AI) to enhance employee support. Key HRM strategies identified include promoting the right to disconnect, implementing flexible work arrangements, advancing digital literacy programs, and responsibly adopting AI-driven interventions. The study emphasizes the shared responsibility of organizations and employees in achieving digital well-being and highlights HRM's pivotal role in aligning employee health with broader organizational sustainability objectives. By combining supportive policies with innovative technological solutions, HRM can foster resilient, adaptable, and productive digital workplaces. This paper offers actionable recommendations to enhance employee resilience, organizational sustainability, and long-term success in a rapidly evolving technological landscape.

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1 Introduction

In the digital era, modern technologies have transformed workplace operations and employee tasks. Digital tools offer unprecedented access to information, resources, and colleagues, enhancing autonomy and enriching experiences across social, professional, and leisure domains (Vanden Abeele, 2021; Vanden Abeele & Nguyen, 2022). However, these benefits come with significant challenges, particularly concerning employee well-being. The pressure to remain constantly connected, manage digital overload, and maintain clear boundaries between work and personal life can result in stress, burnout, and reduced overall employee satisfaction (Derks & Bakker, 2014; Tarafdar et al., 2019).

The digital presence in the workplace has become an essential component of modern professional life. Thus, to enhance their professional reputation and contribute to the success of their organizations, employees are expected to maintain an active online presence. Employees who actively participate in digital channels foster accessibility and openness, enabling colleagues to seek assistance, cooperate in projects, and exchange ideas effortlessly (Tiwari et al., 2024). However, this expectation can blur boundaries between personal and professional life, increasing risks of stress and burnout.

Modern technology is an integral and transformative force in today's workplace. Thus, in today's digitally driven workplace, a well-maintained digital presence has become an essential instrument for professional networking, career advancement, and workplace cooperation. While modern technologies promise to improve productivity and efficiency, they also introduce several issues, including work-life balance, job displacement, privacy, and the necessity for continual learning. The impact of modern technologies on employees' digital well-being is an essential component of this ongoing digital revolution (Tiwari et al., 2024).

Given the pervasive nature of digital technologies in the workplace, HRM professionals face the challenge of fostering environments that support digital well-being. This includes addressing issues related to digital overload, setting boundaries for after-hours communication, and implementing strategies that promote a balanced approach to technology use (Mazmanian et al., 2013; Tarafdar et al., 2019). Recognizing the multidimensional nature of digital well-being, this study adopts a

qualitative synthesis of existing literature to analyze trends and interventions in HRM practices.

This research explores the challenges of digital well-being within the specific context of HRM. While digital well-being has been discussed in broader terms, this study is distinct in its focus on the workplace and the pivotal role HRM plays in addressing these challenges. By analyzing existing literature, this study identifies key interventions HRM professionals can employ to enhance digital well-being. These include promoting work-life balance, preventing digital overload, and building digital competencies among employees. The research provides a novel contribution by integrating theoretical perspectives with practical HRM strategies, offering actionable recommendations for organizations to improve employee well-being in the digital age.

This paper examines the strategic integration of digital well-being into HRM practices, with particular attention to emerging technologies and ESG frameworks. It seeks to analyze existing literature on digital well-being, assess practical interventions that organizations and HR professionals can implement, and identify gaps for future research. By addressing the interplay between technology and well-being, this paper contributes to advancing the understanding of how HRM can shape digital well-being strategies to meet the demands of modern workplaces. The paper addresses the following research question: "How can digital well-being become an integral part of sustainable HRM strategies in the age of AI and ESG compliance?".

2 Theoretical Background

Digital well-being should not be misconstrued as merely episodic satisfaction derived from the utilization of digital technologies. Rather, it necessitates a comprehensive understanding of the interrelationship between well-being and the use of digital technologies (Büchi, 2021). Digital well-being, a continually evolving concept, refers to the ability to achieve a healthy balance between the advantages of digital connectivity and its potential drawbacks (Vanden Abeele, 2021; Ayyagari, Grover, & Purvis, 2011). Aligned with the normative perspective that technology should enhance quality of life (Griffy-Brown, 2018), it encompasses individuals' positive emotional states, life satisfaction within technology-saturated environments,

and specific domains such as job satisfaction and interpersonal relationships (Büchi et al., 2019; Amichai-Hamburger & Furnham, 2007; Floridi, 2014; Gui et al., 2017; Vanden Abeele, 2021).

It is increasingly recognized as essential for maintaining employee productivity, engagement, and mental health in the workplace (Vanden Abeele & Nguyen, 2022; Büchi, 2021). Digital well-being in the workplace aims to address fundamental challenges, such as achieving an optimal work-life balance and reducing screen time (Thomas et al., 2022). Given there is no universally accepted definition, Vanden Abeele (2020) conceptualizes digital well-being as a dynamic system influenced by personal, device, and contextual factors, thereby avoiding simplistic cause-and-effect interpretations.

Digital well-being encompasses various dimensions, including social, psychological, and physical aspects. It examines the impact of digital technologies on an individual's physical and mental health, overall quality of life, job satisfaction, and work-life balance (Tiwari et al., 2024). Moreover, it refers to the emotional, physical, and mental health of individuals within digital environments (Arroyo Moliner et al., 2023).

Given the multidimensional nature of digital well-being, its integration into broader organizational sustainability frameworks, particularly Environmental, Social, and Governance principles, is both relevant and necessary. ESG frameworks have become a cornerstone of sustainable management practices (Liang et al., 2023), encompassing environmental stewardship, social responsibility, and sound governance structures.

From a social (S) perspective, digital well-being directly relates to ESG by emphasizing the health, safety, and general well-being of employees. Prioritizing digital well-being aligns with the core ESG commitment of ensuring decent working conditions, promoting mental health, and fostering an inclusive and supportive organizational culture. Moreover, organizations that actively manage digital stress and prevent burnout through HRM practices demonstrate a clear commitment to social sustainability. This, in turn, enhances employee retention, productivity, and organizational attractiveness.

The governance (G) dimension of ESG is closely linked to digital well-being through policies aimed at regulating digital interactions and technology use. Governance strategies such as transparency in digital communication, clear policies on the right to disconnect (Hopkins, 2024) and accountability in managing digital tools not only enhance well-being but also reinforce organizational integrity and stakeholder trust. Such governance practices help organizations mitigate risks associated with digital overload, data privacy concerns, and ethical challenges posed by digital transformations.

Lastly, although less apparent, the environmental (E) dimension also intersects with digital well-being. Responsible digital practices can contribute to environmental sustainability (Vergallo et al., 2024) by reducing electronic waste, energy consumption, and carbon footprint through moderated technology use, and advocating for sustainable digital consumption patterns among employees. Digital well-being strategies that encourage responsible use of digital resources therefore support broader environmental sustainability goals.

Positioning digital well-being within the ESG context thus provides a holistic framework for organizations. It underscores the interconnectedness between technological management, employee health, organizational governance, and environmental responsibility, contributing to a comprehensive approach to sustainability in the modern workplace.

Nevertheless, implementing these ESG-aligned digital well-being strategies in practice presents numerous challenges. Digital technologies, while neither inherently harmful nor beneficial, significantly influence employee well-being in complex ways (Baym, 2010). The ongoing digital revolution continues to transform how people work, learn (Zolak Poljašević et al., 2024), communicate, and collaborate, simultaneously presenting opportunities and obstacles, particularly concerning employee mental health and work-life balance (Arroyo Moliner et al., 2023). For instance, flexible work arrangements—a hallmark of digital transformation—can enhance productivity and employee satisfaction but may also exacerbate coordination difficulties and create expectations of constant availability, thus complicating ESG-driven efforts to establish clear boundaries and sustainable digital practices.

Furthermore, excessive use of digital devices, such as smartphones, tablets, and laptops, continues to intensify personal and professional demands, exacerbating stress and anxiety due to constant connectivity, increasing productivity expectations, and frequent technological updates (Abeele et al., 2018; Arroyo Moliner et al., 2023). Additionally, technology overuse can lead to significant repercussions, including reduced performance, disrupted sleep patterns, and diminished accomplishments, ultimately hindering employees' potential (Thomas et al., 2022). Persistent distractions from technology further contribute to negative outcomes, such as reduced productivity and heightened susceptibility to technology addiction, thereby challenging the effective operationalization of ESG-aligned digital well-being initiatives (Alosaimi et al., 2016; Kumcagiz & Gündüz, 2016; Thomas et al., 2022).

Research underscores that excessive technology use adversely impacts mental health (Lanaj et al., 2014), sense of agency (Lukoff et al., 2021), self-control (Cheng et al., 2019), and social interaction capabilities (Turkle, 2011). Such adverse outcomes directly undermine the social dimension of ESG by compromising employee well-being, interpersonal relationships, and organizational culture. Additionally, technology-induced distractions and self-interruptions impede focus and exacerbate stress, reducing productivity (Mark et al., 2015; Pielot et al., 2014; Oulasvirta et al., 2012), which further conflicts with governance goals aiming to optimize workplace efficiency, transparency, and accountability in digital environments. Addressing these issues through proactive HRM strategies thus becomes critical for aligning digital well-being with broader ESG objectives.

3 Methodology

This study employs a qualitative desk research approach, synthesizing existing academic literature to explore the role of Human Resource Management in fostering digital well-being within the workplace. By synthesizing and analyzing the existing body of literature, this study identifies key themes and practical interventions related to digital well-being within the organizational context.

A thematic analysis was conducted to organize findings into core areas, such as the impact of digital technology on employee well-being, and HRM strategies aimed at mitigating digital overload. These strategies include preventing digital overload, fostering digital competencies, and promoting work-life balance. This systematic

approach not only facilitated the identification of recurring themes and common challenges but also highlighted best practices and innovative HRM strategies for enhancing digital well-being.

The analysis also integrates theoretical perspectives with practical implications, examining how HRM practices can be adapted to better support digital well-being initiatives in organizations. By synthesizing insights from diverse academic sources, this methodology provides a nuanced understanding of the challenges associated with digital well-being and the HRM strategies that can address these issues. The qualitative approach enables a comprehensive examination of existing literature, setting a robust foundation for actionable recommendations and identifying areas for future empirical research.

4 Results

The findings of this research highlight several key aspects of digital well-being in the workplace, focusing on both challenges and potential solutions. A recurring theme is the pervasive nature of technology, which, while offering immense opportunities for enhancing productivity and communication, simultaneously presents significant challenges for employee well-being. The study underscores that constant connectivity and the associated pressures, such as information overload and blurred boundaries between work and personal life, are among the primary contributors to employee stress and burnout (Thomas et al., 2022).

One of the significant outcomes of this research is the recognition of digital literacy as a cornerstone for fostering digital well-being. Employees equipped with robust digital skills are better positioned to navigate technological changes, reducing frustration and enhancing their adaptability. This finding aligns with existing literature that emphasizes the role of education and continuous learning in addressing the fear of obsolescence and fostering a more confident and capable workforce (Arroyo Moliner et al., 2023).

The research also highlights the effectiveness of implementing supportive organizational policies, such as the "right to disconnect" and the use of digital self-control tools. These measures, when integrated with broader strategies like time management training and mindfulness programs, create a holistic approach to

managing digital demands. The study demonstrates that such initiatives not only alleviate stress but also contribute to a healthier work-life balance, enabling employees to perform at their best without compromising their well-being (Thomas et al., 2022; Roffarello & De Russis, 2023).

HRM plays a central role in achieving digital well-being by designing and implementing these policies and strategies. HRM departments are uniquely positioned to design and implement initiatives that support employees in managing digital challenges, such as fostering digital literacy programs, promoting work-life balance through flexible work arrangements, and advocating for the "right to disconnect." Additionally, HRM can encourage employee engagement with self-regulation tools, such as digital self-control applications, and provide access to continuous learning programs. By integrating these initiatives into organizational practices, HRM ensures a structured and sustainable approach to digital well-being.

A promising direction for the future of digital well-being initiatives involves leveraging AI technologies. The findings suggest that AI has considerable potential to complement existing HRM strategies (Malik et al., 2023), providing organizations with more sophisticated tools for monitoring, managing, and enhancing employee digital health. AI-driven applications can proactively detect signs of digital stress or burnout (Merhbene et al., 2022) by analyzing employees' technology usage patterns and emotional responses, thereby enabling timely interventions. For instance, intelligent digital assistants and Chabot technologies can provide real-time, personalized support and guidance to employees experiencing digital fatigue or stress, significantly enhancing existing HR interventions. Furthermore, AI-powered predictive analytics can enable HRM professionals to anticipate which teams or individuals are most at risk of digital overload (Shetty et al., 2023), allowing them to implement targeted preventive measures more effectively.

The integration of AI into digital well-being strategies also aligns closely with broader organizational sustainability frameworks, particularly ESG principles. AI can enhance the transparency and effectiveness of governance (G) practices by systematically tracking and reporting on digital well-being indicators. Additionally, AI-driven insights can inform social (S) sustainability initiatives, ensuring that employee support systems remain responsive and adaptive to evolving digital demands. However, the research emphasizes that successfully integrating AI into

digital well-being initiatives requires careful ethical consideration (Möllmann et al., 2021; Ashok et al., 2021). Ensuring transparency, accountability, and robust privacy protections is essential to prevent potential misuse of AI and to build employee trust. By responsibly adopting AI technologies, HRM can significantly advance organizational capabilities in maintaining digital well-being, thereby contributing to healthier and more sustainable workplaces in the long term.

The integration of advanced technologies, including AI, further emphasizes the need for gradual familiarization and adequate support resources in facilitating technological transitions. HRM professionals play a crucial role in guiding employees through these transitions by providing targeted training, mentoring, and continuous support mechanisms. By fostering a culture of continuous learning and adaptability, particularly in contexts involving sophisticated technologies such as AI, organizations can significantly reduce resistance to change, enhance technological acceptance, and cultivate innovation and resilience among employees (HeadClear, 2024).

Moreover, the increasingly complex nature of digital well-being highlighted by AI-driven interventions reinforces the shared responsibility between organizations and employees. Employees are encouraged to proactively manage their digital habits, set boundaries, and use available tools—including AI-supported platforms—to safeguard their well-being. Concurrently, HRM must actively support these employee-driven initiatives through customized policies, resources, and innovative programs. HRM's strategic initiatives, such as flexible work arrangements, team-building activities, and mental health programs, can effectively mitigate AI-related risks, including feelings of isolation, digital overload, and elevated stress levels. For example, flexible work policies empower employees with greater autonomy over their digital interactions, while structured team-building exercises and AI-supported mental health initiatives strengthen collaboration and reduce feelings of isolation, particularly in remote or hybrid environments (Bogićević, 2024).

In summary, the results underscore that digital well-being is multifaceted and dynamic, necessitating collaborative, adaptive approaches involving both HRM strategies and technological innovations such as AI. HRM thus emerges as a pivotal player, strategically aligning organizational goals with employee well-being needs through education, supportive policies, and practical interventions. The findings

particularly highlight the importance of continuous evaluation and feedback loops, which are vital to ensuring that HRM practices remain responsive and effective in the rapidly evolving digital and technological landscape. Ultimately, HRM's proactive and adaptive role, reinforced by responsible AI integration, contributes significantly to building healthier, more engaged, and resilient workforces prepared for future challenges.

5 Discussion

HRM should adopt a comprehensive and holistic approach to digital well-being, incorporating supportive work environments, organizational policies, and employee training to develop essential digital competencies. By prioritizing employee well-being, organizations can achieve sustainable improvements in productivity, creativity, performance, and overall job satisfaction (Arroyo Moliner et al., 2023). Moreover, aligning digital well-being initiatives explicitly within ESG frameworks enhances their strategic importance and sustainability. By addressing employee digital health as part of broader ESG objectives, particularly through emphasizing social responsibility and transparent governance, HRM not only supports individual well-being but also strengthens organizational reputation and long-term sustainability.

Employees possess distinct psychological and physiological needs that require careful consideration. Increasingly, employees—particularly younger generations—prefer organizations that prioritize well-being (Bogićević, 2024). Given the pervasive influence of technology, it is imperative to implement measures that ensure a balance between digital demands and well-being (Thomas et al., 2022). Constant connectivity, excessive screen time, and information overload must be addressed as they contribute to stress and burnout (Arroyo Moliner et al., 2023).

One strategy for mitigating these challenges is the implementation of digital self-control tools (DSCTs), which enable employees to regulate their technology usage. For instance, applications can impose time restrictions or track device usage, fostering healthier habits (Roffarello & De Russis, 2023; Lyngs et al., 2019). By integrating DSCTs with policies such as the "right to disconnect," organizations can establish a comprehensive approach to managing digital demands while safeguarding employee well-being. These tools serve as positive reinforcement mechanisms,

helping employees balance productivity and beneficial digital interactions (Thomas et al., 2022). These digital tools can be further enhanced by integrating AI-driven solutions, such as intelligent monitoring applications and chatbots that offer personalized and proactive interventions. AI-supported DSCTs can help employees more effectively manage their digital usage and identify patterns leading to stress or overload, thereby creating more tailored and responsive digital well-being strategies.

Organizations can further support digital well-being by adopting time-tracking systems that promote boundary-setting. For example, software can notify employees when their work hours end, encouraging adherence to a healthy work-life balance (Rozentals, 2022; Bogićević, 2024). Similarly, promoting the "right to disconnect" is critical in mitigating the blurring of personal and professional boundaries. This principle ensures employees can disengage from work-related tasks outside regular working hours, fostering a sustainable work-life balance and preventing burnout (Arroyo Moliner et al., 2023).

Managers should also encourage employees to take regular breaks and adopt techniques like the Pomodoro method, which alternates focused work with short breaks to enhance productivity and prevent exhaustion (Arroyo Moliner et al., 2023). Empowering employees with digital literacy skills is another essential component, enabling them to navigate technological changes effectively and reducing the frustration associated with digital transformations (Arroyo Moliner et al., 2023).

Some employees find it harder to accept changes in the workplace than others. The same applies to the introduction of new digital technologies in workplaces. Employees should not be overwhelmed with new technologies and equipment and expected to use them effectively without proper preparation. Gradual familiarization with technological changes is crucial. Such gradual familiarization and supportive resources not only alleviate employee frustrations but also foster a culture of continuous learning and adaptability within the workplace. Moreover, employees must have access to support resources and know whom to approach when encountering challenges with digital tools (HeadClear, 2024).

Programs to improve employees' digital literacy skills should include educational initiatives on the effective use of digital tools in the workplace, strategies for maintaining a healthy relationship with technology, and time management

techniques. These programs enhance employees' digital competencies, confidence, and job satisfaction while contributing to a more adaptive and effective workforce. Furthermore, continuous learning opportunities help employees stay updated with technological advancements, reducing fears of obsolescence and empowering them to navigate digital workplaces more effectively (Arroyo Moliner et al., 2023). Integrating AI-specific training into digital literacy programs is increasingly vital, enabling employees not only to understand AI technologies but also to actively utilize AI tools to maintain their own digital well-being. This enhances their capacity to adapt to technological shifts, reduces anxieties about AI-driven workplace changes, and supports continuous, self-directed learning.

Setting explicit boundaries for after-work communication, fostering a culture that respects personal time, and promoting breaks are vital in establishing a healthy work-life balance and, thus, enhancing employee well-being (Arroyo Moliner et al., 2023). Both organizations and employees must recognize that work-life balance is a shared responsibility. While employees are encouraged to reassess their priorities and engage in activities that enhance their quality of life, organizations play a pivotal role in enabling this balance. Measures such as flexible work arrangements, remote work opportunities, childcare support, and additional leave days can significantly impact employee satisfaction and well-being (Gričnik & Šarotar Žižek, 2024).

Since the pandemic, remote work has become a standard practice for many organizations. However, the responsibility for managing remote work effectively lies with both employees and employers. Employees should develop efficient work routines while balancing other responsibilities. Simultaneously, organizations should provide education and training programs to support employees in navigating remote work challenges. Annual workshops or training sessions focusing on stress management and well-being can be particularly beneficial (Roffarello & De Russis, 2023). Furthermore, occasional team-building events can mitigate the social isolation associated with remote work, fostering a sense of community and mental well-being (Bogićević, 2024). Organizations utilizing remote and hybrid models particularly benefit from ESG-aligned, AI-driven digital well-being initiatives. AI-based analytics can provide insights into remote workers' digital behavior, helping HRM implement more precise interventions to reduce isolation, maintain productivity, and promote work-life balance in line with ESG social objectives.

Organizations must also address the potential impact of digital stressors on employee mental health. Offering resources such as counseling services, employee assistance programs, and mindfulness workshops can significantly improve employee resilience and well-being. Regular assessments of digital health strategies through employee feedback further enable organizations to refine their approaches and ensure their effectiveness (Arroyo Moliner et al., 2023). Incorporating regular ESG-oriented assessments and leveraging AI-generated insights into these evaluations ensures that digital well-being initiatives remain relevant and responsive. This ongoing alignment allows organizations to continuously enhance their ESG compliance, governance transparency, and adaptability to technological innovations.

Implementing mindfulness and well-being applications in the workplace offers substantial benefits, including enhanced cognitive function, reduced stress, and improved mental health. Such applications have been demonstrated to lower anxiety and depression levels, optimize immune function, and improve daily functioning (Goyal et al., 2014; Neuendorf et al., 2015). Regular use of these tools can also mitigate burnout, reduce fatigue, and foster a healthier workplace environment (Wylde et al., 2017; Lindsay et al., 2018).

Finally, introducing digital detox initiatives—such as establishing unplugged hours or limiting non-urgent messages during specific times—can promote healthier work-life boundaries. By clearly communicating expectations regarding technology use during and outside working hours, organizations can support responsible and balanced engagement with digital tools (Arroyo Moliner et al., 2023).

Ultimately, achieving digital well-being requires a shared commitment from both organizations and employees. By fostering a supportive environment, prioritizing education and training, and implementing policies that respect personal boundaries, organizations can ensure that employees thrive in the digital workplace while maintaining their well-being and productivity. In this context, the strategic alignment of digital well-being with ESG principles and the responsible integration of AI technologies represent essential future directions. Acknowledging digital well-being as a critical ESG component and leveraging AI's capabilities can significantly enhance organizations' capacity to foster sustainable, adaptable, and resilient work environments.

6 Conclusions

This study addresses the research question: How can digital well-being become an integral part of sustainable HRM strategies in the age of AI and ESG compliance? The findings demonstrate that HRM plays a central role in strategically integrating digital well-being within organizational practices, explicitly aligning employee and organizational needs with broader ESG frameworks. By embedding supportive policies and responsible use of emerging technologies such as artificial intelligence, HRM fosters a balance between technological advancement and employee well-being. This balance enhances productivity, mitigates digital stress, and sustains mental health and engagement, thereby strengthening organizational sustainability.

Achieving digital well-being, as evidenced by this research, requires a collaborative approach reinforced by ESG principles and technological innovations. HRM professionals must provide structural and cultural frameworks, while employees actively participate by regulating their digital behaviors and leveraging AI-supported tools. Initiatives such as flexible work arrangements, tailored AI-enhanced training programs, and gradual integration of new technologies are crucial to enabling employees to confidently adapt and thrive in rapidly evolving digital environments.

HRM's significance lies in its capacity to align organizational ESG objectives with individual well-being, positioning digital well-being as a strategic and sustainable priority. By cultivating adaptability, continuous learning, and sustainable digital habits, HRM ensures technological advancements positively impact employee satisfaction, resilience, and overall organizational performance.

Nevertheless, this study has limitations. The reliance on qualitative synthesis of secondary data, while valuable, lacks empirical validation of proposed strategies. Findings primarily address contexts within digitally advanced workplaces, potentially limiting applicability to less technologically developed or resource-constrained environments. Moreover, sector-specific dynamics were not extensively addressed, suggesting an opportunity for future exploration.

Building upon this research, future empirical studies—such as surveys, interviews, or longitudinal case studies—should investigate the effectiveness of ESG-aligned, AI-enhanced digital well-being strategies across diverse organizational contexts.

Exploring how sector-specific factors influence these strategies' outcomes will also provide deeper insights. Furthermore, ongoing investigation into the ethical and practical implications of integrating emerging technologies, notably AI and automation, can reveal additional challenges and opportunities in sustaining employee digital well-being.

In conclusion, HRM plays a pivotal role in achieving and sustaining digital well-being by strategically embedding ESG principles and responsibly integrating AI innovations. By collaboratively addressing the complexities of digital transformation through evidence-based, adaptive strategies, organizations can create resilient, productive, and healthier workplaces, well-equipped to navigate the continuously evolving technological landscape.

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Pilot Study On Pharmaceutical Waste Disposal and Its Role in Sustainable Management

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Significant attention is being given to waste management worldwide, with efforts to reduce waste volumes. While plastics receive the most focus, pharmaceuticals also pose a significant environmental threat. This pilot study on pharmaceutical waste disposal, conducted at a pharmacy in Poland, includes quantitative and qualitative analyses of medicines returned for disposal in two-week intervals. The research provides information about customer practices, revealing that many unexpired medicines are often found in disposal bins, further emphasizing the need for better education. The findings offer valuable insights into the role of pharmaceutical waste management in sustainable practices, addressing the environmental challenges posed by improper disposal. Furthermore, this study highlights the critical responsibility of pharmaceutical manufacturers to ensure the safe and sustainable disposal of their products. Additionally, the improper disposal of pharmaceutical waste generates a significant financial burden on national health systems, further underscoring the importance of responsible waste management practices.

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1 Introduction

Significant attention is being given to waste management worldwide, with efforts to reduce waste volumes. While plastics receive the most focus, pharmaceuticals also pose a significant environmental threat and financially burden national health systems (Rogowska & Zimmermann, 2022). The economic effects of pharmaceutical waste are multifaceted, resulting in increased healthcare costs, loss of financial resources, and broader impacts on public health systems. Such waste leads to the direct loss of financial investment in medications and exacerbates healthcare challenges through the need for additional treatments, putting pressure on already strained healthcare budgets. Non-adherence to prescribed medications contributes to pharmaceutical waste and results in increased overall healthcare expenditures. When patients do not follow their medication schedules, they often require additional medical attention, leading to repeated treatments or hospitalizations that incur extra costs. According to Alshemari et al., the costs associated with treating complications arising from non-adherence can significantly escalate, compounding the economic burden of wasted pharmaceuticals (Alshemari et al., 2020). Thus, addressing adherence improves health outcomes and serves as a mechanism for healthcare cost containment.

Inadequate pharmaceutical waste management systems can lead to indirect economic costs through environmental damage. Pharmaceuticals that enter the environment may cause pollution, necessitating costly cleanup operations and regulatory compliance in public health measures. Additionally, the rise of antibiotic resistance associated with improper disposal of pharmaceutical waste incurs significant expenses in directly treating resistant infections and the economic burden on healthcare systems globally (Alnahas et al., 2020; Mohammed et al., 2021) .

2 Theoretical Background

The disposal of unused drugs and pharmaceuticals is a significant public health and environmental issue. People often resort to various methods of disposal primarily due to a lack of awareness or understanding of proper practices. Research indicates that common disposal methods include throwing medications in household waste, flushing them down toilets, or returning them to pharmacies (Ling et al., 2024; Sarah & Lamyaa, 2016; Yu et al., 2019). When evaluating the motivations behind these

practices, several key factors emerge: knowledge, awareness of environmental risks, and accessibility of take-back programs. One of the most critical reasons for improper medication disposal is the lack of knowledge regarding proper disposal methods. Many individuals do not know that returning unused medications to pharmacies or designated take-back programs is the recommended approach. Studies show that a significant proportion of people dispose of their medications in household waste or sewage simply because they are not aware of safer alternatives (Albaroodi, 2019; Ong et al., 2020; Sarah & Lamyaa, 2016; Seehusen & Edwards, 2006). Additionally, research highlights that those who are educated about these recommended methods are more likely to use them, indicating an inverse relationship between knowledge levels and improper disposal behaviors (Ayele & Mamu, 2018; Ong et al., 2020; Rogowska et al., 2019). Furthermore, public awareness of the environmental consequences of improper disposal is surprisingly low. Although some individuals recognize the potential harm that pharmaceuticals can inflict on ecosystems, many still opt for less environmentally friendly disposal methods. Studies have documented instances in which individuals are aware of the detrimental impacts of such actions but choose to overlook them, possibly due to convenience or perceived low risk (Cook et al., 2012; Dohle et al., 2013; Ling et al., 2024). As noted in various studies, community campaigns aimed at raising awareness about the environmental impact of household pharmaceutical waste have had mixed effectiveness; thus, continued education is essential (Kasprzyk-Hordern et al., 2021; Kusturica et al., 2016; Rogowska et al., 2019). Additionally, accessibility to proper disposal methods plays a crucial role in shaping disposal behaviors. In regions where pharmacy take-back programs are scarce or poorly advertised, individuals are significantly more likely to dispose of medications improperly (Singleton et al., 2017). For instance, surveys indicate that in countries where organized medication return systems exist, like Sweden, a far higher percentage of the population returns medications to pharmacies than in countries with fewer or absent initiatives (Kusturica et al., 2016). The inconsistency of information provided to the public about disposal methods only compounds the issue (Yang et al., 2019).

According to data from the Polish Ministry of Health, in 2023, the total sales value of all prescription drugs amounted to PLN 26.1 billion (PLN 4.2 billion more than in 2022), while the value of reimbursements reached PLN 10.5 billion (PLN 1.9 billion more than in 2022). Patients spent PLN 15.6 billion of their funds on prescription drugs (PLN 2.3 billion more than in 2022). In 2023, reimbursements

accounted for 40.4% of the value of prescription drugs sold (compared to 39.3% in 2022). In 2023, the highest share in the value of sold medicines was held by drugs related to the cardiovascular system (19.2%), the digestive system and metabolism (18.9%), and the central nervous system (13.5%).

This pilot study aims to analyze the scale, structure, and characteristics of pharmaceutical waste returned to a community pharmacy in Poland, with a particular focus on the presence of expired versus unexpired medicines, their therapeutic classification, and the broader implications for environmental sustainability, and pharmaceutical industry responsibility.

3 Methodology

The research methodology was adapted from Romanelli and Lucente (2022). This descriptive study examined a sample of packaged medicines returned by customers to a pharmacy for disposal. In Poland, patients' collection of unused and expired medicines primarily relies on designated pharmacies with special disposal containers. The PSZOK (Selective Municipal Waste Collection Points) is a second option, where patients can bring their pharmaceutical waste. While pharmacies provide convenient and widely accessible drop-off locations, PSZOK facilities offer an alternative for the disposal of larger quantities of pharmaceutical waste alongside other hazardous household waste. When disposing of medicines at pharmacies, it is recommended that they be brought without their cardboard packaging and accompanying leaflets. As a result, the collection containers typically contain only blister packs, bottles, and other primary packaging. The entire study was conducted with precautionary measures in place, using a protective apron, face mask, and disposable gloves.

The analysis occurred in a „Apteka Rodzinna Iwaszko Pawel“ pharmacy located in Dzierżoniów, a city with 30,000 residents in the Lower Silesian Voivodeship, Poland, between the beginning of January and the middle of March 2025. For each collected medicine, the following details were recorded: (1) product name, (2) active ingredient(s), (3) number of remaining dosage units, and (4) expiration date. Based on these records, additional data were derived, including (5) pharmacological classification (according to the 1st or 2nd level of the ATC classification system) and (6) remaining shelf life (in months). The study excluded medicines that could not be

quantified, such as multi-dose liquid formulations (non-transparent bottles) and semi-solid preparations (gels, creams, ointments, etc.). The study concerned one pharmacy and was a pilot study. It aimed to confirm whether the methodology adopted from the cited studies is adequate for the situation in Poland and for collecting unused medicines. All collected data were entered into an Excel file, and descriptive statistics were generated.

4 Results

During the pilot study, 69 kg of waste was analyzed. The average amount of waste collected over two weeks was 11.5 kg (SD 1.2 kg). Analyzed samples comprised 10.71% of dietary supplements and 89.29% of pharmaceuticals. Among pharmaceuticals, 80.67% were past their expiration date, while 19,33% were unexpired at the time of disposal (in the case of dietary supplements, 87.78 % were expired). Full blisters or bottles accounted for as much as 58.40% of all discarded medicines. The sample included unused drugs representing almost all classes according to the Anatomical Therapeutic Chemical classification (table 1).

Table 1: The distribution of unused pharmaceuticals according to the Anatomical Therapeutic Chemical classification.

The Anatomical Therapeutic Chemical (ATC) classification system*	%	% of expired
A Alimentary tract and metabolism	24.13	17.38
B Blood and blood forming organs	3.07	2.50
C Cardiovascular system	15.33	7.86
D Dermatologicals	2.67	2.38
G Genito urinary system and sex hormones	2.93	1.67
H Systemic hormonal preparations, excl. sex hormones and insulins	2.80	1.5
J Antiinfectives for systemic use	5.87	3.33
L Antineoplastic and immunomodulating agents	0.13	0.00
M Musculo-skeletal system	11.20	6.90
N Nervous system	21.20	12.98
P Antiparasitic products	0	0
R Respiratory system	10.53	7.5
S Sensory organs	0.13%	0
V Various	0	0

*WHO Collaborating Centre for Drug Statistics Methodology, Guidelines for ATC classification and DDD assignment 2024. Oslo, Norway, 2023

The most commonly represented categories were Alimentary tract and metabolism (A), accounting for 24.13% of all unused medicines, and Nervous system (N) drugs at 21.20%. These groups include medications for gastrointestinal conditions, diabetes, depression, and chronic pain—indicating challenges with long-term treatment adherence and possible overprescription.

Cardiovascular system (C) drugs comprised 15.33% of the waste, many of which are prescribed for chronic conditions such as hypertension and heart disease. Musculo-skeletal system (M) medications, including anti-inflammatory and pain-relieving agents, accounted for 11.20%. In comparison, Respiratory system (R) drugs made up 10.53%, reflecting episodic use and potentially unnecessary stockpiling of treatments for seasonal illnesses.

Drugs from other therapeutic areas appeared less frequently: Antiinfectives for systemic use (J) represented 5.87%, raising concerns due to the implications of leftover antibiotics on antimicrobial resistance. Genito-urinary system and hormonal treatments (groups G and H) comprised approximately 2.9% and 2.8% of the waste, respectively. Dermatologicals (D) accounted for 2.67%.

Some categories were nearly absent from the waste stream, including Antineoplastic and immunomodulating agents (L) and Sensory organs (S), each representing only 0.13%, and Antiparasitic products (P) and Various (V), both with 0%.

The proportion of expired medications within each ATC group also varied. A notable percentage of expired items was found in categories A (17.38%), N (12.98%), and R (7.5%). These results suggest that many patients do not complete their treatments, discontinue medications due to side effects, or accumulate excess supplies due to therapy adjustments.

Table 2: The distribution of 13 of the most common unused pharmaceuticals according to ATC classes.

ATC Class*	ATC classification	% of collected drugs
Paracetamol OR paracetamol with caffeine	N	3.73
Pantoprazole	B	2.67
Diclofenac	M	2.40
Metformin	A	2.40
Ibuprofen	M	2.00
Tramadol + Paracetamol	N	2.00
Drotaverine	A	1.60
Captopril	C	1.47
Bilastine	R	1.47
Betahistine	N	1.20
Naproxen	M	1.20
Acetylsalicylic acid	B	1.20
Ramipril	C	1.20

*according to the WHO Collaborating Centre for Drug Statistics Methodology, Guidelines for ATC classification and DDD assignment 2024. Oslo, Norway, 2023

Among the most frequently discarded pharmaceutical substances identified in this study were drugs commonly used to treat chronic and widespread medical conditions. Pantoprazole, a proton pump inhibitor, is routinely prescribed for acid-related disorders such as gastroesophageal reflux disease (GERD) and peptic ulcers. Paracetamol and ibuprofen—both widely available over-the-counter analgesics—are used for the treatment of mild to moderate pain and fever, and were frequently found among unused medications, often reflecting over-purchase or precautionary use. Similarly, diclofenac and naproxen, both non-steroidal anti-inflammatory drugs (NSAIDs), are prescribed for musculoskeletal and inflammatory conditions such as arthritis and back pain. Metformin, one of the most commonly used medications for type 2 diabetes, and ramipril or captopril, used for hypertension and cardiovascular disease, represent cornerstone therapies in chronic disease management. The presence of these drugs among unused items may indicate issues with long-term adherence or dosage adjustments made during treatment. Tramadol combined with paracetamol is used for moderate to severe pain and may be discarded due to side effects or resolution of acute symptoms. Drotaverine, frequently used in abdominal or menstrual cramps, and betahistine, used to treat vertigo, suggest the presence of symptom-based prescribing for episodic conditions. Also notable was the disposal of bilastine, an antihistamine used for allergic rhinitis, and acetylsalicylic acid (aspirin), often prescribed in low doses for cardiovascular prevention.

5 Discussion

In the present study, 80.67% of the pharmaceutical items documented in the database were past their expiration date, while 19,33% were unexpired at the time of disposal. This finding aligns with international data on the composition of pharmaceutical waste returned by consumers. A study in Italy reported that 28% of the medications returned to pharmacies had not yet expired, a figure that is remarkably consistent with the proportion observed in our dataset. Comparable percentages of unexpired medicines were also reported in earlier studies conducted in Birmingham (UK) (Mackridge & Marriott, 2016) and Southern California (USA)(Law et al., 2014), suggesting a recurrent trend across different healthcare systems and cultural contexts. In a separate study analyzing residual household waste in Vienna, Austria, the proportion of unexpired medications was slightly higher, at 36% (Vogler & Rooi, 2018). The convergence of these findings suggests that almost one-quarter of pharmaceutical waste may involve medicines still within their shelf life. This phenomenon has important implications for pharmaceutical policy and waste prevention. It reflects a persistent over-prescription, suboptimal adherence, or precautionary stockpiling, particularly without financial or behavioral incentives to complete prescribed regimens.

Given that unexpired medicines often remain pharmaceutically viable, their disposal represents economic loss and a missed opportunity for recovery, redistribution (in regulated contexts), or prevention of waste at source. These insights support the need for targeted interventions such as improved patient education, digital adherence tools, more precise prescribing practices, and potentially take-back systems with eligibility for redistribution where legally and ethically permissible.

Analysis of unused medications according to the Anatomical Therapeutic Chemical (ATC) classification system (Table 1) revealed that certain therapeutic groups are disproportionately represented in pharmaceutical waste. The observed distribution may be partially influenced by recent policy developments—specifically, the introduction of free drug entitlements, effective September 1, 2023, and access to free medications for specific population groups (Act of 13 July 2023). Under this regulation, individuals aged 65 and above are entitled to receive prescribed medications free of charge, provided two conditions are met: the patient has a diagnosed condition that falls within the scope of reimbursement indications, and

the medication is included in the official list of reimbursed drugs. This entitlement has also been extended to children and adolescents under 18. Similarly to seniors, eligible young patients must have a confirmed diagnosis aligned with the reimbursement criteria, and the prescribed medication must be listed in the national reimbursement register. The list of medications available free of charge to children and adolescents includes a broad spectrum of therapeutic categories, such as antihistamines, hormonal agents, immunostimulants, antibacterial, antifungal, and antiviral drugs, as well as analgesics, anticonvulsants, anti-infectives, and vaccines. Importantly, the list of free medications is dynamic and subject to regular updates—potentially several times per year—reflecting changes in therapeutic standards, market availability, and health policy priorities. This measure aims to reduce economic barriers to pharmaceutical access among vulnerable age groups and support adherence to prescribed therapies in chronic and acute conditions.

The data (Table 1) indicates that waste is not solely associated with acute therapies. Many of the most wasted medications are used for chronic or age-related conditions, aligning with the therapeutic needs of older adults, particularly those over 65, who are newly entitled to free medications in Poland. While the policy increases access, it may unintentionally contribute to stockpiling or reduced adherence without adequate monitoring and patient support. Introducing a policy providing free pharmaceuticals to specific patient groups could significantly impact the disposal practices of unused drugs brought to pharmacies. Such initiatives often lead to increased availability of medications, which may result in a higher surplus of unused drugs if patients do not adhere to prescribed regimens or receive a greater quantity than necessary. This scenario could exacerbate the issue of drug waste, thereby heightening the environmental risks associated with improper disposal practices. One study highlights that unused medications contribute to household waste, with many individuals discarding these drugs improperly by throwing them into regular garbage or flushing them down toilets (Vogler et al., 2014; Ayele & Mamu, 2018). In environments where free drug policies are implemented, an influx of pharmaceuticals without adequate patient education about responsible use and disposal may increase the volume of drugs requiring safe disposal. Research indicates that many households lack awareness about the appropriate means of disposing of medications, often resorting to unsafe practices that can lead to contamination of local environments. For instance, household disposal practices have been shown to lead to significant levels of pharmaceutical contaminants in landfills and water

sources (Insani et al., 2020; Kahsay et al., 2020). Moreover, take-back programs are central to mitigating this waste issue. Evidence suggests that when consumers are provided with accessible take-back options—such as designated drug disposal sites within pharmacies—they are more likely to return unused medications (Kahsay et al., 2020; , Alghadeer & Al-Arifi, 2021). Countries like Sweden and the USA, which have established structured drug take-back systems, demonstrate how convenience can enhance participation in safe disposal practices (Abuassonon et al., 2019). However, if free drug policies are not accompanied by public educational campaigns about the environmental impacts of drug waste and the importance of utilizing these take-back systems, the effectiveness of these programs may be compromised. Research shows how specific disposal education can bolster public participation in drug take-back schemes, revealing that individual knowledge directly influences proper disposal behavior (Amoabeng et al., 2022). This situation underscores the importance of a comprehensive approach combining the provision of free drugs with robust educational initiatives aimed at promoting both medication adherence and environmentally responsible practices. Additionally, it should be noted that perceptions of responsibility towards proper disposal also play a crucial role. Studies indicate that a significant percentage of the public believes they should take responsibility for drug disposal, yet they often lack the necessary information or systems to facilitate proper behavior (Bean et al., 2016; , Alghadeer & Al-Arifi, 2021). Thus, as free drug policies expand access, it becomes paramount to integrate educational efforts about safe disposal and implement accessible return systems to ensure that increased supply does not translate to elevated environmental harm.

The pharmaceutical substances most frequently identified in the collected waste suggest distinct age-related usage patterns. Several medications are strongly associated with older adults, particularly those used to manage chronic conditions (Atella et al., 2019). For example, pantoprazole, ramipril, captopril, metformin, and acetylsalicylic acid (aspirin) are commonly prescribed for patients over the age of 50, particularly for managing hypertension, type 2 diabetes, cardiovascular disease, and gastrointestinal conditions (Cena et al., 2020; Glossmann et al., 2019; Reid et al., 2018; Salvatore et al., 2020). The high presence of these drugs in the waste stream may reflect issues such as polypharmacy, non-adherence, therapeutic substitution, or discontinuation due to side effects—factors particularly relevant in older populations. Other medications, such as tramadol with paracetamol and diclofenac, are also commonly used among older adults and middle-aged individuals for

managing chronic pain, osteoarthritis, and post-operative conditions (Findikli & Altun, 2016; Scott & Perry, 2000). The disposal of these agents might result from changes in pain management strategies or concerns about long-term use and safety in older patients.

As a key stakeholder in the pharmaceutical supply chain, industry actors must not only prioritize access and efficacy but also address the environmental and social consequences of product disposal. This includes supporting take-back programs, investing in eco-design of packaging and formulations, and collaborating with public health agencies to promote responsible medicine use. The study may indicate that the pharmaceutical industry's responsibility is not only the scope of developing and delivering safe and effective medicines, but also participation in ensuring the responsible disposal of unused and expired products. In line with the European Commission's definition of ESG and corporate social responsibility (CSR)—which frames CSR as the duty of enterprises to manage their societal impacts—pharmaceutical firms are uniquely accountable, given the direct consequences of their operations on human and environmental health. CSR in the pharmaceutical sector increasingly includes mechanisms like product take-back programs, improved distribution forecasting, and consumer education to reduce over-prescription and waste (Tat et al, 2021, Sabbaghnia et al, 2024).

Despite growing attention to these initiatives, the current data demonstrate persistent inefficiencies in medicine use, with a significant percentage of drugs being disposed of before their expiration. This trend contributes to environmental pollution, risks to public health, and unnecessary financial burdens on healthcare systems. Moreover, studies such as Droppert and Bennett (2015) highlight that CSR strategies often emphasize health systems strengthening and local partnerships, but rarely integrate structured pharmaceutical waste management as a core business responsibility. As pharmaceutical companies evolve from philanthropic models toward shared value strategies, a more explicit integration of waste reduction and circular economy principles is warranted. Addressing medicine waste must become a pillar of the pharmaceutical industry's CSR agenda, aligned with sustainable development goals and stakeholder expectations in high-income and low- and middle-income countries. In addition, there is a direct link to at least two sustainable development goals, i.e., ensure healthy lives, promote well-being for all ages (SDG 3), and ensure sustainable consumption and production patterns (SDG 12).

6 Conclusions

Conducting research following the adopted scheme may be further continued and scaled up to a broader level, allowing for more comprehensive data collection and deeper analysis. Building on these initial findings, future research should explore several complementary areas. First, longitudinal studies could track seasonal or policy-related variations in pharmaceutical waste volumes and composition. Second, comparative studies across different pharmacy settings—urban vs. rural, public vs. private—would offer broader insights into patient behavior and disposal practices. Moreover, qualitative research involving patient and pharmacist interviews could deepen the understanding of motivations behind improper disposal, medication non-adherence, or precautionary stockpiling. Special attention should be paid to the impact of public reimbursement policies, such as the free drug entitlement for seniors and minors, on drug overuse and wastage.

From the circular economy perspective, increased pharmaceutical waste undermines the principles of resource efficiency and responsible consumption. Medicines are complex, high-value products involving intensive raw material usage, energy consumption, and emissions throughout their lifecycle—from production to disposal. An increase in unused medicines translates to increased demand for new production and intensifies the environmental footprint of the pharmaceutical supply chain.

Furthermore, medicine disposal programs' logistics and financial burden fall largely on health systems and local authorities. As the volume of returned medications grows, so do the costs of collection, sorting, and high-temperature incineration—often the only environmentally acceptable method for safe pharmaceutical waste treatment. These factors necessitate integrating waste prevention strategies into pharmaceutical policy, including more personalized prescribing, improved patient education, and systematic analysis of disposal trends.

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The Impact of Relationships, Leadership and Innovation on Organisations

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In the current turbulent and competitive environment, organizations continually strive to enhance their market position through inter-organizational relationships. Today, in an organization innovation plays a key role in the process of building an effective operating model. On the other hand, developing interpersonal relationships, and leadership behavior is desirable in response to the increasing demands of a turbulent environment. The author researched a sample of 622 business sector managers. The tools used were a questionnaire survey and a diagnostic survey, and, as a result, structural models were used. As a result, it was found that the type of relationship between members of an organization, the type of leadership, and innovation are correlated. The analysis shows that innovative behavior is better solved in organizations with strong leadership and, on the other hand, leaders' flexibility affects their relationships. It appears that there is relatively little research on how interpersonal relationships affect the generation and diffusion of new solutions. In this context, the results discussed and the conclusions drawn from them can be seen as an addition to the existing body of work, which should be further extended.

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1 Introduction

In the current turbulent and competitive environment, organizations continually strive to enhance their market position through interorganizational relationships. Collaboration among entities serves as a vital avenue for organizations to bolster their competitive edge (Berman et al, 2024). This collaborative effort engenders a synergy effect, thereby augmenting access to advanced technological resources (Bańkowski & Rzepka, 2024).

The role of leaders in this context is of paramount importance. Cortellazzo et al. (2019) assert that effective collaboration necessitates leaders who not only demonstrate strong managerial capabilities but also possess interpersonal skills, empathy, and flexibility. Such attributes enable leaders to adeptly navigate the complexities inherent in today's global landscape (Rzepka & Witkowski, 2023), thus facilitating the establishment and maintenance of robust interorganizational relationships.

Leaders significantly influence the quality of both internal and external relationships, which in turn impacts team dynamics and overall organizational effectiveness. Rzepka (2023) emphasizes that the success of teams is closely tied to the competencies of their leaders, highlighting the necessity for leaders to exhibit agility in adapting to the evolving business and technological trends.

In summation of the aforementioned literature review, it is crucial to acknowledge that scholars recognize the intrinsic relationship between organizational leadership and innovation However, a notable paucity of research persists regarding the extent to which team relationships influence innovativeness. It remains to be determined whether the nature of interactions among employees is a significant factor that translates into their capacity to generate and implement new solutions

2 Literature review

Innovation is a key characteristic of an organisation in an era of ever-changing environment and associated constant challenges. Innovation is seen by many scholars (Wierzbicka -Mazur, 2020, Garita &Martinez, 2016) as a process combining science, technology, economics and management to achieve novelty and extending

from the emergence of an idea to its commercialisation or as new knowledge introduced into products, services and processes (Kogabayev&Maziliauskas, 2017;). It is worth noting the link between creativity and innovation as shown, for example, by Meutia et al (2018),Leino (2022) or Harrari (2021). These authors point out that creativity is the initial phase of innovation. On the other hand, Roy &Mohapatra (2023), Furtner et al (2018) or Rzepka & Sabat (2022) note the far-reaching relationship between being creative and being innovative.

As defined by Appio et al. (2024), a leader exerts a positive influence on other employees without resorting to coercive tactics. Their attitude depends on a set of soft skills (e.g. communication, creativity, dynamism, adaptability) that directly shapes their management style (and how others perceive them. The primary objective of a leader is to optimize the potential and competences of other employees (Wilson, 2022). Nowadays, when organizations largely operate based on the VUCA concept (volatility, uncertainty, complexity, and ambiguity), leaders must exhibit agility and flexibility, and need specific competences across various domains such as social competence (e.g. empathy), organizational acumen (e.g. organizing work), strategic thinking (e.g. planning), and technological literacy (e.g. analyzing data) (Sty'ven et al.2022) .

The theme of inter-organizational relationships has been extensively explored within the academic literature. Bellis et al. (2024) posit that the advancement of innovative activities necessitates that leaders adopt ambidextrous approaches, allowing them to adeptly navigate diverse environments while adapting their behaviors and styles, all the while upholding consistency in their values and norms. Contemporary researchers emphasize that the adaptation of innovation should concentrate on critical dimensions such as collaboration, prototyping, adaptability, experimentation, risk management, and data-driven development.

3 Methodology

The research presented herein is part of an international initiative titled "Teal Organizations in Economy 4.0," conducted across various countries including Poland, England, Hungary, India, Spain, Georgia, and the USA. This study comprised an initial preliminary phase followed by three subsequent stages of actual research. The research sample consisted of 622 respondents, selected through

random sampling methods. A proprietary survey questionnaire was used as a tool, distributed according to the standards of the CAWI (Computer-Assisted Web Interviewing) technique and consisting of thematic blocks relating to the leader/leadership in the organisation, innovations and technologies used in the company, prevailing relationships, agility and creativity, social capital, knowledge and information, trust and structure, organisational culture. The questionnaire consisted of 5 parts, each with 5 - 7 closed questions focusing on different topics. The employed research techniques included CAWI and Computer-Assisted Personal Interviewing (CAPI). The research was conducted by the recommendations established by the OECD-DAL. The survey targeted individuals employed within Polish enterprises. Furthermore, analytical methods such as the Cronbach alpha test, the ANOVA method, and the F test (Fisher-Snedecor) were utilized. Statistical analyses were performed using SPSS STATISTICA software, ensuring rigor and reliability in the findings. One of the limitations of the research was access to particular groups of respondents. The author pointed out the generalisation of the groups without breaking them down into the main sections of the SME's activities.

Table 1: Scope of business activity

		A - Preliminary stage	B- Primary research	C– Repeated tests
Primary modus operandi (%)	Trade	19.7	10.3	16.6
	Production	17.6	13.9	28.0
	Services	62.7	75.8	55.4
Geographic scope of operation (%)	Local	19.3	22.1	9.4
	Regional	8.2	12.4	27.3
	National	30.0	23.0	22.0
	International	42.5	42.4	41.3
Number of employees (%)	0-9	13.7	9.1	3.3
	10-49	24.0	18.8	55.1
	50-249	15.5	28.2	16.6
	250-999	18.5	20.9	16.6
	1000-and	28.3	23.0	8.4

Source: Own research

4 Findings

As previously stated, a leader's role is related to the process of influencing people to achieve expected results. A total of 44.2% of respondents agreed that good leaders should strive to shape their subordinates' independent thinking and responsibility

for their actions, while 34.7% strongly agreed. Only 2.1% of respondents disagreed with this statement, and 18% were undecided.

Table 2: Statements regarding a company leader

	I strongly disagree	I disagree	Hard to say	I agree	I strongly agree
In relations with subordinates, a good leader should strive to shape their independent thinking and responsibility for their actions	1.0	2.1	18.0	44.2	34.7
Vision is a characteristic of a good leader that unites and inspires the team to act	0.6	3.4	19.1	38.9	37.9
Humility is a characteristic of a good leader thanks to which they have the ability to acknowledge they have been wrong	0.3	3.2	18.6	42.9	34.9

Source: own research

As shown in Table 1, over 70% of respondents agree with the qualities of a good leader, i.e., vision, inspiring teams to act (38.9% and 37.9%, respectively). Similarly, regarding humility (i.e., good leaders should admit when they are wrong), more than 76% of respondents agreed with the statement (columns 4 and 5). Good leaders know, appreciate, and respect their colleagues; they motivate them to do fruitful work, show support during times of difficulty, and have all the prerequisites needed to manage a team effectively. Leaders have specialist skills such as knowledge and professional qualifications, innovative skills, creativity, and analytical thinking (Rzepka 2023). However, the most important characteristics are interpersonal skills related to team building. A leader with all the qualifications to manage who cannot communicate with the group will not succeed. According to my research, the effectiveness of a leader also depends on having skills that can be learned and constantly improved, regardless of one's predispositions. The leader should master social skills in effective team building and leading, i.e., the ability to communicate effectively, listen actively, provide feedback, motivate to achieve goals, have a positive self-presentation, solve problems, and exhibit assertive behavior. An effective leader should also be a visionary, an entrepreneur, an initiator, and a person open to spontaneous changes.

5 Discussion

In contemporary society, a leader or manager is no longer perceived merely as an individual who issues directives from the apex of a hierarchical structure. Instead, effective management is predicated on collaboration with the team, often assuming a supportive role. This collaborative approach has been demonstrated to be essential for fostering positive performance, productivity, and motivation. Research indicates that initiatives aimed at enhancing teamwork, such as team-building exercises, have a beneficial impact on team effectiveness and overall success. Team leaders frequently assume a critical role in steering their teams toward success, drawing upon both intuition and factual analysis to cultivate a leadership style that transcends mere data. A team leader is responsible for setting the tone, providing direction, and facilitating effective collaboration among team members.

As Rzepka and Sabat (2022) assert, the willingness to adopt new, creative solutions is a determining factor in the effective utilization of acquired knowledge, which is crucial for the successful implementation of innovative initiatives. Conversely, a turbulent environment can catalyze the emergence of novel types of intra-organizational relationships that have not previously existed, thereby playing a vital role in the innovation processes (Maziriri et al.2024)

James et al., 2022). The establishment of robust intra-organizational relationships may stem from knowledge-based agility and managerial decisions regarding the pursuit of new opportunities.

As demonstrated, the role of the leader is multifaceted. On one hand, leaders establish the developmental direction of their organizations; on the other hand, they motivate individuals to exert effort. Change is an inherent aspect of our lives; embracing it becomes a pivotal moment for any organization.

As evidenced by the aforementioned research (Rzepka, 2020; 2023), leaders in the 21st century must embody the qualities of artists, possessing the ability to adapt swiftly within the workplace, where the talent for establishing relationships, fostering creativity, and initiating change ultimately defines overall success. Consequently, contemporary leadership is grounded in the capacities to relate, create, and initiate, as well as in enhancing the agility of leaders, managers, and their teams. However,

many current leaders and managers have yet to acquire these essential skills. In fact, research indicates that the organization itself often serves as the primary barrier to skill development.

6 Conclusions

Indeed, a multitude of scholars recognize that the types of leadership employed within organizations have a substantial impact on the various dimensions of organizational functioning previously considered. For example, Gren and Ralph (2022) along with Reunamäki and Fey (2022) contend that leaders who adhere to traditional leadership styles characterized by supervision and control can detrimentally affect the agile thinking and behaviors of the teams they lead. In contrast, a leader who seeks to cultivate and empower others to realize their utmost potential should embody a range of essential leadership qualities. These qualities include listening, empathy, awareness, persuasion, conceptualization, foresight, a commitment to the development of individuals, stewardship, and community building (Knoll, 2019). It is imperative to note that such empowerment is not only vital for individual development but also plays a significant role in enhancing innovation and creativity within the organization.

In summary, a turbulent environment, can initiate new types of intra-organisational relationships that have not occurred before, which can play a critical role in innovation processes (Aničić 2024**)**. Strong intra-organisational relationships can result from knowledge-based agility and managerial decisions about whether to act on new opportunities. As Hutton et al. (2024) note, the organisation itself can develop the ability to respond to different situations (agility) through staff rotations, which enhances the skills of selected individuals contributing to open innovation.

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Eco-Conscious Consumerism and Purchase Intention Towards Alternative Fuel Vehicles – An Examination

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The increasing urgency to stop climate change and lower greenhouse gas pollution has made Alternate Fuel Vehicles (AFVs) a popular way to travel that is also good for the environment. A wide range of vehicles are considered AFVs, such as electric vehicles (EVs), hybrid vehicles, hydrogen fuel cell vehicles, and vehicles that run on biofuels or compressed natural gas (CNG). This kind of vehicle is made to use less fossil fuels, put out less CO2, and be a cleaner option to regular vehicles that run on petrol or diesel, However, despite the potential of AFVs, several challenges remain in promoting their widespread adoption. Additionally, in collectivistic societies like India, social norms play a major role in influencing the purchase intention of consumers. Therefore, getting inspiration from the Value-Belief-Norm Theory, this study tried to find out how eco-conscious consumers' behavior influence their intention to purchase AFVs (personal values, attitudes, personal norms, social norms and purchase intention towards AFVs). Data was collected from 269 respondents through a structured questionnaire. The findings show that personal values, such as concern for the environment and social influences, like peer and societal expectations, play a significant role in encouraging consumers to choose AFVs.

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1 Introduction

India has an interesting opportunity to study eco-friendly consumer behavior because of the differences in ecological and cultural set up. The country does have serious air pollution problems more so in the cities, making it compulsory rather than optional to embrace clean forms of transport. Urban consumers' understanding of environmental issues, which is coupled with enhanced sense of responsibility towards sustainability, has led to a change in their consumption pattern. This change is marked by increasing preference for eco-friendly products, such as Alternative Fuel Vehicles (AFCs), which are seen as tangible efforts towards alleviating the negative impact on the environment. In Indian society, the concept of social responsibility and social good are deep archetypes that guide people's choices and actions. Environmentally conscious individuals, for instance, are often able to act in compliance with their inner beliefs because of the cultural values they comprise. Such cultural and normative influence encourages the readiness of the society for the adoption and integration of AFVs. Therefore, this study was conducted to answer the question: How do eco-socially conscious consumer behaviors influence the adoption of AFVs among people?

The paper is structured as follows: The first chapter of this paper is the introduction. The second chapter provides a theoretical overview of relevant literature on the topic. This is followed by a section on the research methodology. The fourth chapter presents the results, followed by the fifth chapter discussing the key findings. The conclusion summarizes the research contributions and suggests directions for future studies.

2 Theoretical Background / Literature Review

Irene (2013) study examined how Greek consumers embraced environmentally friendly behaviors, that is, ecologically conscious consumer behavior (ECCB). It probed the factors responsible for pro-environmental action, namely demographics such as age and income, attitudes, and personality traits. According to Rezvani et al. (2015) and Zhang et al. (2021), the growing adoption of electric vehicles (EVs) is influenced by advancements in technology, rising environmental awareness, and financial benefits. Factors such as access to charging infrastructure, vehicle performance, and supportive policies play a crucial role in shaping consumer

decisions. This paper reviews the current state of EV research, identifies gaps in understanding long-term consumer behavior, and suggests future directions to address challenges and promote wider EV adoption. Naz Onel (2016) explores how personal norms, along with the Theory of Planned Behavior (TPB), shape consumers' choices to buy environmentally friendly products. The study found that personal and social norms play a key role in driving eco-friendly purchasing intentions. Analyzing data from 281 participants, the research showed that while attitudes and intentions matter, perceived behavioral control doesn't strongly predict buying intentions. This highlights the need for marketing strategies that focus more on the influence of social and personal norms. By integrating personal norms into the TPB, the study offers useful insights for encouraging sustainable consumer behavior.

Degirmenci and Breitner (2017) examined what drives people to consider buying electric vehicles (EVs), focusing on environmental benefits, cost, and driving range. Their study, which included 167 test drives and surveys, found that the environmental performance of EVs—like reducing pollution and saving natural resources—plays a bigger role in shaping consumer attitudes and purchase decisions than price or range limitations. Carley et al. (2013) also looked at factors influencing EV adoption but emphasized the importance of owning an EV for personal environmental image rather than its actual environmental impact. Similarly, Junquera et al. (2016) focused on price and range concerns but did not explore the environmental aspect, which Degirmenci and Breitner addressed by showing how EVs contribute to sustainability. Bockarjova and Steg (2014) highlighted the risks of traditional fuel vehicles, reinforcing the need for studies like Degirmenci and Breitner's to position EVs as a cleaner, greener alternative.

Varshneya et al. (2017) explored how green values and social norms shape people's decisions to buy organic clothing. They found that personal values, like caring for the environment, play a much bigger role in influencing purchase intentions than social pressure, especially in emerging markets. Similarly, Thøgersen and Zhou (2012) observed that even in collectivist cultures like India, people tend to make individual choices when it comes to adopting new and niche products, prioritizing their environmental concerns over fitting in. These findings shed light on why there's often a gap between people's attitudes and their actual buying behavior for green products. Bennett and Vijaygopal (2018) explored how stereotypes about

electric vehicle (EV) owners and the alignment of self-image with EV users affect consumer attitudes and their willingness to purchase EVs. Through a gamification approach, the study found that playing a game where participants took on the role of an EV driver improved their perception of EV owners and made them feel more connected to the idea of owning an EV. While this shift in attitude was positive, it did not strongly influence their willingness to buy an EV, as this connection was moderated by how favorable the stereotype was and how closely participants identified with EV users. The study highlights the importance of marketing EVs using relatable role models and improving public perceptions to make EV ownership more appealing.

Abid, Eagle, and Low, (2021), suggest that the study applied Value-Belief-Norm (VBN) theory to investigate which factors influence eco-socially conscious consumer behavior (ESCCB) towards alternative fuel vehicles (AFVs). It appeared that personal norms, more so introjected and integrated norms, were a good predictor of ESCCB by influencing both the desire to acquire and conserve AFVs. Lee et al. (2023) explored what motivates people to adopt electric vehicles (EVs) by combining two key theories: the Value-Belief-Norm (VBN) theory and the Theory of Planned Behavior (TPB). They found that people who prioritize altruistic and environmental values are more likely to be aware of environmental impacts and develop a sense of moral responsibility, while those with self-centered values are less likely to do so. The study highlights the need to address personal values and social influences, along with practical factors like attitudes and perceived control, to encourage more people to switch to EVs.

Enggar Handarujati (2024) looks at the factors that shape people's intentions to buy electric cars by combining three well-known theories: the Theory of Planned Behavior (TPB), the Norm Activation Model (NAM), and the Technology Acceptance Model (TAM). The study focuses on how perceived usefulness and control influence consumer decisions. By analyzing data from 253 participants using structural equation modeling, the research shows that these theories together offer a clearer picture of what drives people to choose eco-friendly transportation. It also helps fill gaps in understanding the various factors that impact these purchasing decisions.

The Value-Belief-Norm (VBN) Theory might be instrumental in understanding sustainability-oriented behavior of consumers. Personal values, beliefs, and norms influenced by VBN theory shapes how individuals perceive and act on environmentally friendly ideas. These factors shape their environmental beliefs and practices, which later, affect choices such as acceptance of AFVs. Therefore, in this study the conceptual model is created taking inspiration from combining TPB and the VBN theory, to test the relationship between the following variables: Egoistic values (EGO), Altruistic values (ALT), Awareness of Consequences (AC), Ascription of Responsibility (AR), Social Norms (SN), Personal Norms (PN), and Eco-conscious Consumer Purchase Intention (ECCPI).

3 Methodology

The study used a quantitative research approach to explore the behavioral factors that influence eco-conscious customers in adopting alternative fuel vehicles. The sample frame of this study consisted of 269 respondents, aged 18 years and above. A convenience sampling method was chosen for its practice advantages, such as easy access to respondents. The study used a quantitative research approach using a questionnaire as a research tool, aimed at gathering insights into respondents' personal values (egoistic and altruistic), attitudes, and behavioral intentions. The questionnaire includes items measured on a Five-point Likert scale (1 – Strongly disagree to 5 – Strongly agree) to capture respondents' perceptions and behaviors regarding alternative fuel vehicles. It was distributed among the target group through online platforms to ensure broader reach and higher response rates. **Section 1** covered questions on consumer demographics and **Section 2** covered questions measuring behavioral constructs such as environmental attitudes, personal values, awareness of alternative fuel vehicles, and intention to adopt these vehicles. A pilot study was carried out to test the reliability and clarity of the questionnaire before the main data collection. The initial questionnaire consisted of 40 items, however, during the pilot analysis, five items were identified as problematic due to certain reasons. To ensure the quality and accuracy of the survey, these items were removed. This resulted in a final questionnaire with 35 items, which was then used for the study. Descriptive analysis and Structural Equation Modeling were employed to test the hypotheses.

4 Results

Majority of the respondents are younger individuals, with 49.1% under the age of 26, and 25.3% between 26-33 years. The next largest group, aged 34-41, accounts for 16.4%, while those aged 42-49 and above make up a smaller portion of 9.2%. This clearly highlights that the study is dominated by younger participants, with older age groups being less represented. These insights are particularly relevant for understanding how younger, eco-conscious individuals perceive and adopt AFVs. The gender distribution of the respondents also shows a slight predominance of female participants. Out of the total 269 respondents, 54.3% are female, while 45.7% are male. This balanced yet female-leaning representation offers valuable insights into the perspectives of both men and women, which could be particularly relevant when analyzing eco-conscious behaviors and their influences on the adoption of AFVs. Out of the 269 respondents, the largest group consists of students at 33.5%, followed closely by those employed full-time at 32.7%. Self-employed individuals make up 15.6%, while part-time employees account for 8.6%. Smaller groups include homemakers (5.6%), those unemployed and looking for work (3.7%), and a very small number of retired individuals (0.4%).

The results of hypotheses testing are given below:

H1 – Awareness of Consequences (AC) is positively related to Ascription of Responsibility (AR)

The link between AC and AR is strong and significant. With a p-value of 0.00, the data suggests that when individuals are more aware of the environmental consequences of their actions, they tend to feel a greater responsibility to act. This indicates that awareness is an important factor in fostering a sense of personal responsibility towards the environment.

H2 – Ascription of Responsibility (AR) is positively related to Personal Norms (PN)

The relationship between AR and PN is also highly significant (p-value = 0.00). This shows that when people feel a sense of responsibility for the environment, they are more likely to develop personal norms, or internal moral obligations, to act in an environmentally responsible way.

H3 – Social Norms (SN) is positively related to Eco-conscious Purchase Intention (ESCCPI)

SN significantly influences ESCCPI (p-value = 0.00). This means that social influences, such as expectations of family, peers, or society, play a critical role in shaping individual's decisions to engage in sustainable consumption and purchasing behaviors. Social pressure to act sustainable can strongly motivate individuals to make more environmentally friendly choices.

H4 – Altruistic values (ALT) positively relates to Awareness of Consequences (AC)

The relationship between ALT and AC is also supported, with a t-statistic of 3.448, and a p-value of 0.001. This indicates that individuals with stronger altruistic values, who care about the welfare of others, are more likely to be aware of the broader environmental consequences of their actions. This finding highlights the role of altruism in enhancing awareness of environmental issues, which can motivate individuals to engage in more sustainable behaviors.

H5 – Egoistic values (EGO) positively relates to Awareness of Consequences (AC)

The hypothesis that EGO influences AC is supported, with a t-statistic of 2.763 and a p-value of 0.006. This shows that individuals with egoistic values, who are primarily motivated by self-interest, still tend to be aware of the consequences of their actions. However, this relationship is somewhat weaker compared to other variables, indicating that egoistic individuals may not be as strongly motivated by the broader environmental consequences as those with more altruistic values.

H6 – Social Norms (SN) positively relates to Personal Norms (PN)

The hypothesis that SN influences PN is also supported with a t-statistic of 5.213 and a p-value of 0.00, indicating a strong and significant positive relationship. This suggests that individuals are more likely to adopt personal ethical standards related to sustainability when they are aware that such norms are prevalent in their social environment.

H7 – Personal Norms (PN) positively relates to Eco-conscious Purchase Intention (ESCCPI)

The result is supported with a t-statistic of 3.102 and a p-value of 0.002, which indicates a statistically significant positive relationship between the two variables. This suggests that individuals who hold strong personal norms regarding environmental sustainability are more likely to have the intention to purchase eco-sustainable products.

5 Discussion

The results highlight that eco-friendly purchase intentions are significantly influenced by personal and social factors. Altruistic values and social norms play a key role in shaping personal norms, which, in turn, drive sustainable purchasing behavior. Environmental awareness strongly impacts individuals' sense of responsibility by increasing awareness of consequences and accountability. While egoistic values have a smaller impact, they still contribute to environmental responsibility indirectly. The study also emphasizes the importance of personal norms as a bridge connecting social influence, environmental awareness, and values to sustainable purchase intentions. Encouraging personal responsibility through environmental education and positive social reinforcement can effectively promote eco-friendly behaviors. Despite a growing awareness of environmental issues, the adoption of AFVS is hampered by practical challenges. Key barriers include the high initial cost of AFVs, limited charging infrastructure, and insufficient knowledge of their long-term benefits. The perception of risks associated with new technologies, coupled with a lack of trust in manufacturers' claims about vehicle performance, also deters potential adopters.

6 Conclusions

Demographically, the study highlights the potential of younger, educated individuals as early adopters of sustainable technologies. However, barriers such as affordability, infrastructure gaps, and perceived risks continue to limit the adoption of AFVs. Addressing these challenges requires a collaborative effort from policymakers, industry stakeholders, and environmental advocates. By aligning strategies with consumer values, leveraging the power of social norms, and fostering a sense of personal moral responsibility, stakeholders can accelerate the transition to sustainable transportation. Educational initiatives, coupled with targeted marketing and supportive policies, have the potential to create a ripple effect, driving not just individual behavior but also broader societal change. In conclusion, the adoption of AFVs is not merely a technological shift but a cultural transformation.

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Modelling Emotional Intelligence Development in Entrepreneurs: Strategic Approach

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Emotional intelligence (EI) is a key competency for successful entrepreneurship. Interest in the development of EI in education is growing rapidly and requires strengthening the methodological base. A systematic literature review brought together the latest knowledge in different fields and revealed the opportunity for fundamental development of the EI of entrepreneurs. This study aims to provide a detailed description of the 4-component instrumental model of EI development for entrepreneurs (4EIE Model), based on combining the latest knowledge in psychology and entrepreneurship. The 4EIE Model consists of 4 main components (namely Self-Awareness, Self-Management, Social Awareness and Relationship Management), according to the latest version of D. Goleman's mixed model and supporting the development of 15 important entrepreneurial competencies, according to the EntreComp conceptual model. The 4EIE Model is convenient to use in a university environment.

Keywords:
emotional intelligence, model, entrepreneurial competences, entrepreneurship, components of emotional intelligence

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1 Introduction

The concept of emotional intelligence (EI) entered mainstream discourse following the publication of D. Goleman's seminal work (Goleman, 1995), in which EI was positioned as a pivotal construct in understanding human behaviour and interpersonal effectiveness. According to D. Goleman, EI is the ability to identify one's feelings and those of others, to motivate oneself, and to manage emotions in both one and others effectively (Goleman, 1995). The model of D. Goleman is called a mixed model (Cherniss & Goleman, 2001). It combines some approaches to EI: the ability-based model by Mayer and Salovey (Mayer et al., 2000) and *the trait-based* model by Petrides (Petrides & Furnham, 2001).

Over the past 30 years, interest in EI has increased and taken an interdisciplinary direction. In the Web of Science databases, the focus on EI has shifted from psychology to education (Figure 1).

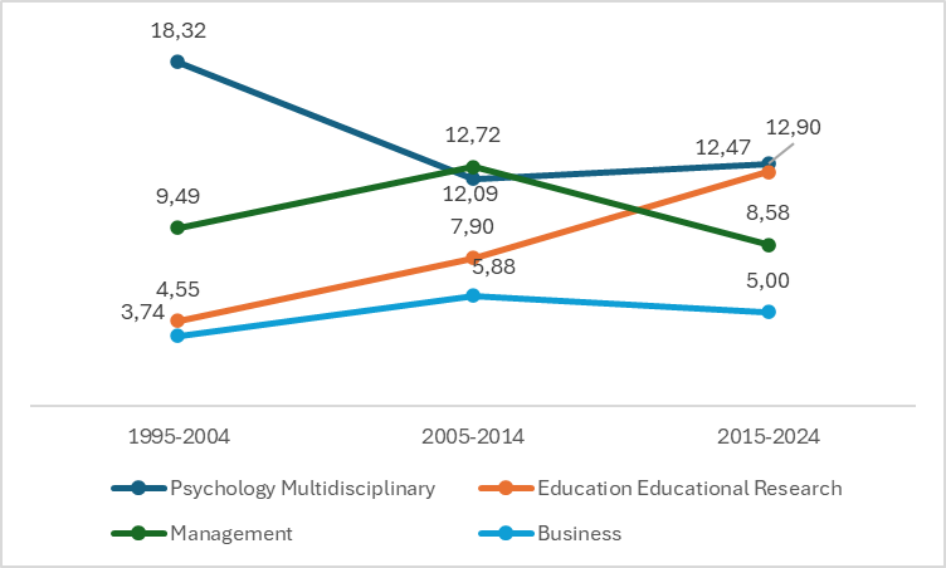

Figure 1: The scientific publications on the topic of EI in the last 30 years in WoS
Source: WoS, own elaboration

The categories of management and business retain the leading positions in terms of EI topics. The main challenge in these areas remains quantifying employee EI's impact on a company's financial performance. Despite the identification of a positive correlation between employee EI and customer loyalty (Bayighomog & Arasli, 2022), EI and leadership skills (Gardner & Stough, 2002), EI and saving time in achieving the desired results (Zhang & Hao, 2022), EI and building high-performing groups (Jin et al., 2012), EI and reduced turnover intention (Uzunbacak et al., 2022), it is still difficult to establish a direct quantitative impact of EI on company's financial performance. The main problem in quantifying the benefits of EI is the inability to separate EI from other types of human capital (Fedorova, 2020)

However, the annual increase in scientific research (Figure 2) enriches the understanding of the composition of EI, allowing knowledge to be pooled in interdisciplinary studies.

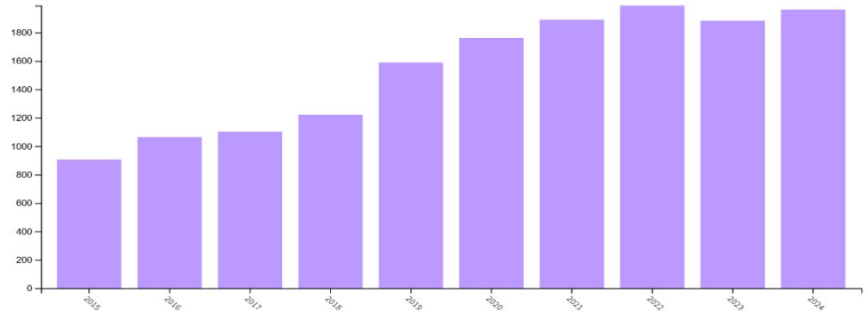

Figure 2: The scientific publications on the topic of EI in the last 10 years in WoS
Source: WoS

The positive impact of EI on success in entrepreneurship is shaping new challenges in the educational environment. The next logical step in training future entrepreneurs is to strengthen the methodological basis of entrepreneurs' EI development, which includes the latest research in psychology, management, and business. Some studies highlight the importance of self-awareness for entrepreneurial success (Crespí et al., 2022) and emphasise the roles of self-awareness, self-regulation, social awareness, and social skills in entrepreneurship

(Chien-Chi C, 2020). We have identified a gap in the methodology for teaching EI to entrepreneurs.

This paper aims to form a model for developing the entrepreneur's EI based on synthesising knowledge in psychology and entrepreneurship. This approach aligns with Sustainable Development Goals such as #3 quality education and #4 good health and well-being (United National, 2015). The development of future entrepreneurs' EI contributes to increasing the efficiency of higher education. It allows entrepreneurs to be prepared to build effective intergenerational collaborations with the older generations in the labour market (Perez-Encinas et al., 2021).

2 Theoretical Background

Emotions and entrepreneurial passion play a crucial role in successful entrepreneurship (Lu X et al., 2022). Understanding the composition of EI has been expressed through the evolution of models of EI development. The three fundamental models of EI development are the EI ability model by Mayer and Salovey, Bar-On's Emotional-Social Intelligence model and the emotional competencies model focused on the workplace by Goleman (Cherniss & Goleman, 2001).

The EI model of mental abilities by Mayer and Salovey (Mayer & Salovey, 1997; Brackett & Salovey, 2006) is regarded as the most foundational, as it is derived from the analysis of a substantial number of theoretical studies and substantiated by empirical evidence from both basic and applied fields. It consists of 4 key components: perceiving emotions, using emotions to facilitate thought, understanding emotions, and managing emotions. These branches encompass recognising emotions, leveraging emotions to enhance thinking, comprehending emotional dynamics, and regulating emotions in oneself and others.

Bar-On's Emotional-Social Intelligence model (Bar-On, 2005) is more complex than Mayer and Saloway's EI Model. It consists of 5 high-level factors with 15 subfactors: 1) Intrapersonal Skills refer to the ability to be aware and understand emotions, feelings, and ideas in the self (subfactors: Self Regard, Emotional Self Awareness, Assertiveness, Independence, Self-Actualization); 2) Interpersonal Skills refer to the

ability to be aware and understanding emotions, feelings, and ideas in the others (subfactors: Empathy, Social Responsibility, and Interpersonal Relationship; 3) Adaptability refers to the ability to be open to change our feelings depending on the situations, (subfactors: Reality-Testing, Flexibility, and Problem-Solving; 4) Stress Management refers to the ability to cope with stress and control own's emotions (subfactors: Stress Tolerance and Impulse Control), and lastly, 5) General Mood refers to the ability of feeling and expressing positive emotions, and being optimistic (subfactors: Optimism and Happiness) (Bar-On, 2005).

The emotional competencies model by Goleman, which focuses on the workplace, is the most appropriate as it focuses on applying EI in a business environment. Initially, this model (Goleman, 1995) contained 25 competencies divided into five components: motivation, self-management, empathy, self-awareness, and social skills (Goleman, 1995). This version is still most often cited in scientific studies of EI. However, Goleman's Model was later simplified, motivation was excluded (Wolff, 2005), and currently, Goleman's model contains four components (self-awareness, self-management, social awareness, and relationship management) with 18 competencies (Cherniss & Goleman, 2001).

Thus, in the evolution of scientific thought on EI in the field of practical application, a convenient and uncomplicated model of EI consists of 4 components: self-awareness, self-management, social awareness, and relationship management. Based on Goleman's model, the 4EI Model (Mikuš et al., 2022) was developed for the business environment, which also contains four components but 19 different competencies. Based on the above models and considering the entrepreneur's competencies, this paper proposes the 4-component instrumental model of entrepreneurial EI development (4EIE Model).

The key and emotionally coloured traits in the entrepreneurial decision-making process are passion and well-being (Davis et al., 2017; Dijkhuizen et al., 2018), optimism and other emotional characteristics (Hubner et al., 2020; Haddoud et al., 2022), and high emotional stability (Hachana et al., 2018). Research into emotions in entrepreneurship has experienced a steady annual increase (Lu X et al., 2022).

3 Methodology

This study is based on models closely aligned with the work environment, including the latest version of Goleman's model (Cherniss & Goleman, 2001) and the Entrepreneurship Competence Framework (EntreComp) developed by the European Commission (Bacigalupo et al., 2016). We systematically searched Web of Science databases using the keywords 'entrepreneurial competencies', 'self-awareness', 'self-management', 'social awareness' and 'relationship management'. We selected the most significant studies of EI in psychology and management, business, and entrepreneurship and identified correlations between important competencies of entrepreneurs and essential components of the 4-factor model of EI development. EntreComp outlines 15 core entrepreneurial competencies essential across European countries and serves as a foundation for entrepreneurship education.

4 Results

We define entrepreneurship as a process of seizing opportunities and ideas and converting them into value for others (Ffe-Ye, 2012). The core entrepreneurial skills encompass a range of attributes, including entrepreneurial passion, teamwork skills, collaborative attitude, trust-building, open-mindedness, long-term goal orientation, self-determination, conscientiousness, intergenerational reflection, resilience, empathy, responsibility, analytical thinking, willingness to learn, and cultural awareness (Lojda et al., 2021; Perez-Encinas et al., 2021), entrepreneurial passion and optimism (Lu X at el., 2022). However, we believe that the most important competencies of an entrepreneur are presented in the methodology of EntreComp, which is well-recognised in the countries of the European Union.

Figure 3 shows the 4-component instrumental model of entrepreneurial EI development (4EIE Model).

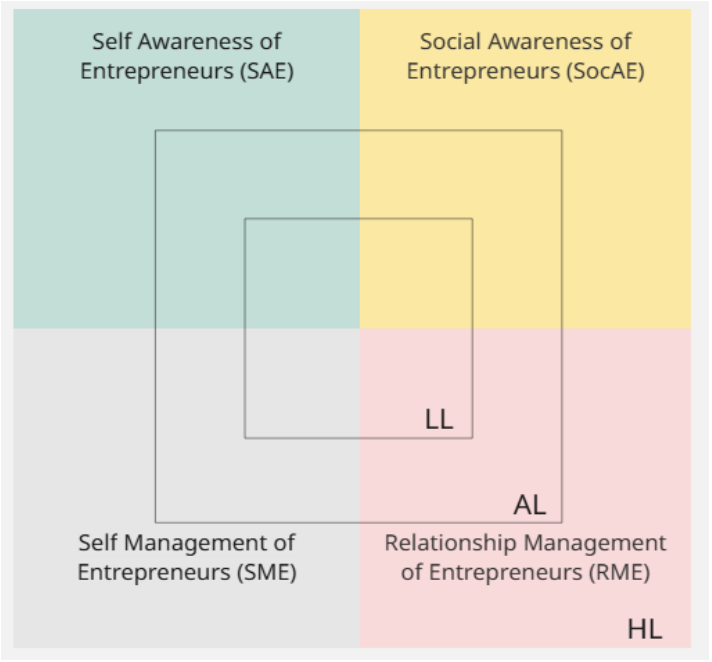

Figure 3: The 4EIE Model
Source: own elaboration

The 4EIE Model consists of the following components namely Self-Awareness of Entrepreneurs (SAE), Self-Management of Entrepreneurs (SME), Social Awareness of Entrepreneurs (SocAE), and Relationship Management of Entrepreneurs (RME). The model helps to build an entrepreneur's EI profile. The 4EIE Model uses the Stan scale from 0 to 10. For every component, the results from 0–3 is a low level (LL), more than 3 to 7 is an average level (AL), and more than 7 to 10 is a high level (HL). The 4EIE Model consists of quadrants equal to the component's value (0 to 10).

The respondent EI profile may look like this: $\{HL^{SAE}; HL^{SME}; HL^{SocAE}; AL^{RME}\}$.

Table 1 presents the components of the 4EIE Model and describes the entrepreneurial competencies they provide.

Table 1: The components of the 4EIE Model (source: own elaboration)

EI component	EI component in Entrepreneurship
Self-awareness (SA) emphasizes the significance of being aware of one's emotions and understanding their impact on personal performance (Cherniss & Goleman, 2001).	**SAE** is the ability to identify opportunities for creating value, generate new ideas, think strategically, analyse, plan and forecast based on understanding one's motives, behaviours, weaknesses and strengths Entrepreneurial competencies of EntreComp that EI develops: Spotting opportunities, Creativity, Vision, Valuing ideas, Ethical and sustainable thinking, Self-awareness and self-efficacy, Financial and economic literacy, Learning through experience, and Planning and management.
Self-management (SM) is the ability to regulate distressing effects like anxiety and anger and to inhibit emotional impulsivity. (Cherniss & Goleman, 2001)	**SME** is the ability to control one's behaviour to achieve one's goals, to adapt, to take responsibility, be motivated, use time and resources effectively under conditions of risk and uncertainty. Entrepreneurial competencies of EntreComp that EI develops: Self-awareness and self-efficacy, Mobilising resources, Motivation and perseverance, Taking the initiative, Planning and management, and Coping with uncertainty, ambiguity and risk.
Social awareness (SocA) enables individuals to understand their surroundings and recognize how their behavior affects, and is affected by, the feelings and emotions of other people (Cherniss & Goleman, 2001).	**SocAE** is the ability to understand and empathise with the emotions of colleagues, team members, investors, consumers, and stakeholders, accept differences of other cultures and generations, uphold corporate culture, and foster teamwork. Entrepreneurial competencies of EntreComp that EI develops: Spotting opportunities, Ethical and sustainable thinking, Working with others, and Mobilising others.
Relationship Management encompasses a range of competencies, including mentoring and developing others, exerting influence, effective communication, managing conflicts, leading teams, driving change, fostering connections, and promoting teamwork and collaboration (Cherniss & Goleman, 2001).	**RME** is the ability to build the effective communications and cooperation, healthily resolving conflicts, leadership, and the ability to inspire and manage a team and realise the potential of team members. Entrepreneurial competencies of EntreComp that EI develops: Coping with uncertainty, ambiguity and risk, Taking the initiative, Mobilising others, Working with others, and Learning through experience.

The 4EIE Model assumes a sequential development of components from SA to RM.

5 Discussion and Conclusion

The literature analysis has revealed the growing interest in EI in education and the lack of a methodological background for the development of EI in entrepreneurs. The synthesis of the latest knowledge in psychology and entrepreneurship made it

possible to propose the 4EIE Model for developing EI in entrepreneurship. The 4EIE Model is built on four core components—Self-Awareness of Entrepreneurs, Self-Management of Entrepreneurs, Social Awareness of Entrepreneurs, and Relationship Management of Entrepreneurs —based on the updated version of D. Goleman's mixed model and supports the development of 15 essential entrepreneurial competencies outlined in the EntreComp conceptual framework. The 4EIE Model is useful for developing entrepreneurs' EI in the educational environment. This work fills the gap in the methodological base in the development of entrepreneurs' EI. The study is interdisciplinary and corresponds to the trend of EI development in the educational environment. The next step is to create a questionnaire, based on which it will be possible to build individual and group EI profiles of entrepreneurs.

Acknowledgements

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THE PRESENTATION OF FINANCIAL STATEMENTS WITHIN THE FRAMEWORK OF THE PUBLIC SECTOR ACCOUNTING STANDARDS: A COMPARISON OF DMS, EPSAS, AND IPSAS

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This study examines Türkiye's compliance with the European Public Sector Accounting Standards (EPSAS) in the context of its European Union (EU) membership process. While Türkiye has already aligned its public accounting system with International Public Sector Accounting Standards (IPSAS), the potential adoption of EPSAS introduces new regulatory challenges. The study analyzes the conceptual framework of public sector accounting standards, comparing EPSAS, IPSAS, and Türkiye's existing regulations. A case study on a municipal financial reporting system is used to highlight practical differences. Findings indicate that while Türkiye's IPSAS-based framework provides a strong foundation, full EPSAS alignment requires additional modifications to comply with EU-specific fiscal rules such as the Maastricht Criteria and the European System of Accounts. The study contributes to the discussion on international accounting harmonization and its implications for candidate countries.

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1 Introduction

Türkiye's European Union (EU) accession process requires the alignment of its economic and financial structures with EU standards. In this context, although Türkiye has adopted the International Public Sector Accounting Standards (IPSAS) in its public financial management, compliance with the European Public Sector Accounting Standards (EPSAS), which are implemented at the EU level, remains a critical issue in the accession process (European Commission, 2021). EPSAS aims to enhance transparency, accountability, and comparability in public finance reporting across EU member and candidate countries while ensuring alignment with the Maastricht Criteria and the European System of Accounts (ESA 2010) (Eurostat, 2020). While Türkiye's IPSAS-based accounting reforms represent significant progress, the official adoption of EPSAS within the EU may necessitate Türkiye's compliance with this framework.

Significant reforms have been implemented to improve Türkiye's public accounting system, particularly with the adoption of Law No. 5018 on Public Financial Management and Control, which introduced fundamental changes based on the principles of fiscal transparency and accountability (T.C. Official Gazette, 2003). Türkiye has modernized its accounting system in line with IPSAS; however, as the development of EPSAS is still ongoing, its impact on Türkiye's EU accession remains uncertain (Brusca & Montesinos, 2018). The transition from a cash-based to an accrual-based accounting system, as outlined in EPSAS, is a crucial step toward ensuring consistency and standardization in financial reporting. Although Türkiye's IPSAS-compliant framework shares similarities with EPSAS, there are specific differences related to EU regulations and the Maastricht Criteria (IFAC, 2020). Therefore, the necessity of full compliance with EPSAS and its potential implications for Türkiye's public financial management should be thoroughly assessed.

This study aims to analyze Türkiye's alignment with EPSAS and evaluate the potential opportunities and challenges associated with this transition. First, the general development of public sector accounting standards is examined, followed by an analysis of the fundamental principles of EPSAS and Türkiye's current situation. Finally, the necessary adjustments for Türkiye's compliance with EPSAS and the potential impact of this process on its EU accession are discussed. Aligning public

financial management reforms with EU accounting standards and international best practices will strengthen Türkiye's fiscal discipline and enhance its integration into global reporting frameworks. Compliance with EPSAS will contribute significantly to Türkiye's EU accession process by advancing fiscal transparency and public accountability.

2 Theoretical Background / Literature Review

2.1 Public Accounting Standards and Presentation of Financial Statements

Public accounting standards are a set of rules designed to ensure transparency, reliability, and comparability in public sector financial reporting (IFAC, 2020). In order to improve financial management and accountability in the public sector, financial statements must be prepared within certain standards. In this context, the International Public Sector Accounting Standards (IPSAS) and the European Public Sector Accounting Standards (EPSAS) stand out as regulatory frameworks in public accounting (Brusca & Montesinos, 2018). Türkiye has aligned its public accounting system with IPSAS through the Public Financial Management and Control Law No. 5018, and the potential for alignment with EPSAS is also an issue to be considered in the context of its EU accession process (T.C. Official Gazette, 2003).

The Purpose and Key Principles of Public Accounting Standards

The main objective of public accounting standards is to ensure accountability and financial transparency in the public sector (OECD, 2019). These standards allow public institutions to report on their financial position and performance reliably. The key principles used in public accounting are as follows:

- Accrual Basis: Refers to recognizing financial transactions when they occur, independent of cash flows. IPSAS and EPSAS are based on accrual-based reporting (Eurostat, 2020).
- Transparency: Information related to public finances must be reported in a clear and understandable manner (European Commission, 2021).

- Comparability: A standard framework is required to compare financial data across different periods and countries. EPSAS is developed to ensure that financial data within the EU is compatible (Brusca et al., 2021).
- Accountability: Refers to reporting how public resources have been used to relevant stakeholders accurately and completely (IFAC, 2020).

Conceptual Framework for the Presentation of Financial Statements

Public sector financial statements are key tools providing basic information for evaluating the effective use of public resources. Public sector financial reporting under IPSAS and EPSAS is based on a specific conceptual framework. IPSAS 1 and the proposed structure of EPSAS include elements such as the balance sheet, statement of financial performance, cash flow statement, and statement of changes in equity (Eurostat, 2020).

EPSAS aims to create a structure compatible with the European System of Accounts (ESA 2010) to ensure financial transparency within EU member states (European Commission, 2021). While the current financial reporting structure in Türkiye is IPSAS-based, if EPSAS is officially adopted, Türkiye may need to make changes to its financial statement presentation. In this context, it is important to analyze the differences between EPSAS and IPSAS during Türkiye's EU accession process (Brusca et al., 2021).

Harmonization of Accounting Standards in the Public Sector

Harmonizing public accounting standards at the international level increases financial transparency and ensures more effective management of public finances (OECD, 2019). While EPSAS allows for the integrated evaluation of financial data among EU member states, IPSAS has a broader global perspective (IFAC, 2020). Aligning Türkiye's public accounting standards with EPSAS can strengthen financial integration with the EU and provide an important advantage in the accession process (Eurostat, 2020).

However, the development process of EPSAS is not yet complete, and it has not been fully implemented across EU member states (European Commission, 2021). Türkiye's alignment with IPSAS may ease the transition to EPSAS; however,

additional regulations may be required within the Maastricht Criteria and ESA 2010 framework (Brusca & Montesinos, 2018). Particularly, full compliance with EU standards regarding budget deficits, public debt management, and fiscal discipline will be crucial factors shaping Türkiye's transition to EPSAS.

In conclusion, the process of harmonizing public accounting standards should be addressed as a strategic issue within the framework of Türkiye's EU membership perspective. If EPSAS is implemented, the transformation of Türkiye's current accounting system and its effects on public finance should be evaluated in detail.

3 Applied Analysis Using a Municipality Example

3.1 Example Municipality and Accounting Processes

To examine the applicability of public sector accounting standards, one of the large municipalities in Türkiye has been selected as a case study. Municipalities are required to manage their accounting systems in accordance with specific standards to ensure the effective, economic, and efficient use of public resources (Brusca et al., 2019). In Türkiye, municipalities prepare financial reports in accordance with the Government Accounting Standards=Devlet Muhasebesi Standartları (DMS=GAS) under the Law No. 5018 on Public Financial Management and Control (T.C. Court of Accounts, 2021).

3.2 Accounting Standards Used by the Municipality

In Türkiye, municipalities are transitioning from a cash-based accounting system to an accrual-based accounting system. The Government Accounting Standards applied by municipalities are designed to be compatible with the International Public Sector Accounting Standards (IPSAS) (IFAC, 2020). However, in the context of the European Union (EU) alignment process, the European Public Sector Accounting Standards (EPSAS) should also be considered (European Commission, 2022).

3.3 Analysis of Financial Statements within the Framework of GAS, EPSAS, and IPSAS

The primary financial statements prepared by municipalities include the statement of financial position, the statement of financial performance (income statement), and the cash flow statement. The differences between GAS, EPSAS, and IPSAS have been evaluated based on these financial statements.

3.3.1 Statement of Financial Position (Balance Sheet)

The statement of financial position shows the municipality's assets, liabilities, and net assets at a specific point in time. IPSAS and EPSAS recommend that municipalities report their assets at fair value, while GAS records certain assets based on historical cost (PwC, 2021). For example, a municipality's buildings are updated at market value according to IPSAS, while they may be recorded at historical cost under GAS (OECD, 2023).

Table 1: Comparative Balance Sheet of a Municipality According to IPSAS and EPSAS (As of 31 December 2023)

Balance Sheet Item	IPSAS (TRY)	EPSAS (TRY)	Explanation
Current Assets	18,000,000	18,000,000	Structurally similar; EPSAS requires more detailed disclosures.
- Cash and Cash Equivalents	10,000,000	10,000,000	Essential for liquidity management.
- Tax and Fee Receivables	4,000,000	4,000,000	Collection risk is assessed for public receivables.
- Other Current Assets	4,000,000	4,000,000	EPSAS mandates transparent reporting of such assets.
Non-Current Assets	132,000,000	132,000,000	EPSAS emphasizes service capacity and long-term public value.
- Tangible/Intangible Fixed Assets	115,000,000	115,000,000	EPSAS includes revaluation and useful life considerations.
- Construction in Progress	15,000,000	15,000,000	EPSAS includes social value impact in assessment.
- Long-Term Receivables	2,000,000	2,000,000	
Total Assets	**150,000,000**	**150,000,000**	EPSAS requires higher transparency and harmonization with EU reporting.

Balance Sheet Item	IPSAS (TRY)	EPSAS (TRY)	Explanation
Current Liabilities	9,000,000	9,000,000	EPSAS demands classification by maturity and nature.
Non-Current Liabilities	30,000,000	30,000,000	Maastricht criteria compliance is considered under EPSAS.
- Long-Term Loans	20,000,000	20,000,000	Debt is categorized based on EU statistical requirements.
- Pension and Social Liabilities	10,000,000	10,000,000	EPSAS requires actuarial assumptions and disclosure of pension gaps.
Total Liabilities	**39,000,000**	**39,000,000**	
Net Assets / Net Worth	111,000,000	111,000,000	EPSAS highlights service capacity and financial sustainability.
- Government Contributions / Capital	80,000,000	80,000,000	
- Surplus of the Current Period	31,000,000	31,000,000	Under EPSAS, must be linked to performance reports.
TOTAL LIABILITIES AND NET ASSETS	**150,000,000**	**150,000,000**	

This table compares the structure and reporting requirements of International Public Sector Accounting Standards (IPSAS) and European Public Sector Accounting Standards (EPSAS) for a hypothetical municipality. While the numerical presentation remains largely consistent, EPSAS mandates more comprehensive disclosures, alignment with EU fiscal frameworks, and statistical reporting obligations (European Commission, 2023; IPSASB, 2022).

3.3.2 Income Statement

Municipalities' revenues typically consist of tax revenues, transfers from central government, and service revenues. IPSAS and EPSAS recommend that revenues be recorded on an accrual basis, while under GAS, some revenues are recorded on a cash basis (IFAC, 2020). For instance, property tax revenue due in 2023 but collected in 2024 should be reported as 2023 revenue according to IPSAS and EPSAS, but it may be recorded in 2024 under GAS (European Commission, 2022).

Table 2: Comparative Statement of Financial Performance of a Municipality According to IPSAS and EPSAS (For the Year Ended 31 December 2023)

Statement Item	IPSAS (TRY)	EPSAS (TRY)	Explanation
Revenue	88,000,000	88,000,000	Revenue categories are similar, but EPSAS requires linking to budget and output performance.
- Tax Revenues	35,000,000	35,000,000	Local taxes such as property and environmental taxes.
- Transfers from Central Government	28,000,000	28,000,000	Intergovernmental fiscal transfers. EPSAS may require statistical reporting.
- Fees and Charges for Services	18,000,000	18,000,000	Fees collected from public services.
- Other Operating Revenue	7,000,000	7,000,000	Includes fines, penalties, and rental income.
Expenses	57,000,000	57,000,000	Expense recognition under EPSAS is based on accruals with detailed function-based classification.
- Personnel Costs	20,000,000	20,000,000	EPSAS also includes disclosure on pension obligations and long-term liabilities.
- Goods and Services	16,000,000	16,000,000	Includes operating and administrative expenditures.
- Depreciation and Amortization	5,000,000	5,000,000	EPSAS may include service potential disclosures.
- Social Benefits	6,000,000	6,000,000	Paid social transfers.
- Other Expenses	10,000,000	10,000,000	Includes interest, grants, and contingencies.
Surplus for the Period	**31,000,000**	**31,000,000**	EPSAS links surplus/deficit to key performance indicators and statistical data.

3.3.3 Cash Flow Statement

The cash flow statement shows the municipality's cash inflows and outflows. IPSAS and EPSAS suggest separating cash flows into operating, investing, and financing activities to enhance transparency, whereas GAS provides less detail in this separation (Brusca et al., 2019).

Table 3: Comparative Cash Flow Statement of a Municipality According to IPSAS and EPSAS (For the Year Ended 31 December 2023)

Cash Flow Category	IPSAS (TRY)	EPSAS (TRY)	Explanation
Cash Flows from Operating Activities	35,000,000	35,000,000	EPSAS aligns with ESA 2010 principles; both use indirect or direct method.
- Cash Inflows from Taxes and Transfers	55,000,000	55,000,000	Includes local tax collections and government grants.
- Payments to Employees and Suppliers	(20,000,000)	(20,000,000)	Operating payments including wages, goods, and services.
Cash Flows from Investing Activities	(15,000,000)	(15,000,000)	Both standards include acquisitions and disposals of non-financial assets.
- Purchase of Property, Plant and Equipment	(17,000,000)	(17,000,000)	EPSAS encourages service value and environmental impact disclosures.
- Proceeds from Sale of Assets	2,000,000	2,000,000	Disposal of obsolete municipal assets.
Cash Flows from Financing Activities	(5,000,000)	(5,000,000)	EPSAS may require classification of borrowing by EU statistical codes.
- Loan Repayments	(5,000,000)	(5,000,000)	Reflects debt servicing.
Net Increase/(Decrease) in Cash	**15,000,000**	**15,000,000**	EPSAS requires reconciliation with budget execution and treasury data.
Cash and Cash Equivalents at Beginning	5,000,000	5,000,000	
Cash and Cash Equivalents at End	**20,000,000**	**20,000,000**	

3.4 Applicability of Accounting Standards in Municipalities and Challenges Encountered

The implementation of GAS, EPSAS, and IPSAS-compliant accounting systems in municipalities faces several challenges. One of the major issues is that municipalities lack sufficient technical infrastructure and human resources to fully transition to accrual accounting (OECD, 2023). Additionally, the applicability of EPSAS standards remains uncertain for non-EU member countries, and specific alignment mechanisms need to be developed for candidate countries such as Türkiye (European Commission, 2022). Furthermore, the complexity of these standards remains a significant challenge, particularly in municipalities with limited capacity to manage detailed financial reporting systems. According to a study by the OECD (2023), the intricacy of aligning local accounting practices with international

standards such as EPSAS and IPSAS often leads to delays and inefficiencies in implementation. This challenge is exacerbated by the lack of standardized procedures across municipalities, further hindering consistent application of these accounting frameworks.

4 Results and Conclusions

The international harmonization of public sector accounting standards is of critical importance for financial transparency and accountability. Türkiye has largely aligned its accounting and reporting processes with IPSAS under the framework of Law No. 5018 on Public Financial Management and Control. However, since the European Public Sector Accounting Standards (EPSAS) process has not been completed, Türkiye's transition to these standards remains uncertain. In this context, the differences encountered in the application of public accounting standards, Türkiye's adaptation to EPSAS and IPSAS, and the challenges faced in the implementation process should be addressed in detail.

Evaluation of Differences in the Application of Public Sector Accounting Standards

The application of public sector accounting standards varies between countries. While IPSAS aims to standardize public sector accounting globally, EPSAS represents a more regional harmonization process developed for European Union (EU) member states (Brusca et al., 2021). In Türkiye, the transition from a cash-based to an accrual-based accounting system in the public sector has shown certain differences. Particularly, the integration of accounting records with budgeting processes varies across different countries (Eurostat, 2020).

On the other hand, although EPSAS is based on IPSAS, it includes specific regulations tailored to the financial systems of EU member states, creating a new transition process for countries like Türkiye (European Commission, 2021). Factors such as the Maastricht Criteria and the European System of Accounts (ESA 2010) must be considered in the EPSAS harmonization process.

Current Status of EPSAS and IPSAS Alignment in Türkiye

Since 2005, Türkiye has implemented various reforms to align public financial management with international standards. Under the framework of Public Accounting and Reporting Standards (KAMUS), regulations based on IPSAS have been adopted, and the transition to accrual-based reporting has been achieved (T.C. Official Gazette, 2006). However, with the entry into force of EPSAS, a reassessment of the differences between Türkiye's current accounting standards and EU regulations will be necessary.

When comparing EPSAS and IPSAS, Türkiye's current accounting structure is largely aligned with IPSAS, but full integration with EPSAS will require additional regulations. For example, the new obligations brought by EPSAS regarding the reporting of public sector debt and budget deficits could necessitate changes to Türkiye's financial reporting system (Brusca & Montesinos, 2018).

Moreover, since the EPSAS process has not yet been fully implemented by the European Commission, the transition to these standards remains uncertain for countries like Türkiye. If EPSAS is implemented, Türkiye will need to adapt its current IPSAS-compliant system to EPSAS, which will bring new financial regulations (Eurostat, 2020).

Challenges in Practice and Recommendations

Various challenges are encountered in the implementation of public accounting standards. Although Türkiye's public accounting system is largely aligned with IPSAS, the main challenges encountered in practice are as follows:

Deficiencies in the Transition to Accrual-Based Accounting: Türkiye has not fully transitioned to accrual-based accounting, and cash-based practices continue in certain areas. This situation may lead to uncertainties regarding the long-term financial management of public finances (OECD, 2019).

Incompatibilities between Budgeting and Financial Reporting: The inability to fully integrate the budgeting system with accounting reporting complicates the comprehensive evaluation of financial statements in the public financial management process (European Commission, 2021).

Uncertainty of EPSAS: The fact that EPSAS has not yet been fully implemented complicates the harmonization process for EU candidate countries like Türkiye. There is no clear framework for the changes required in Türkiye's accounting system should it transition to EPSAS (Eurostat, 2020).

The following solutions are proposed to address these challenges:

Strengthening Accounting Training: In order to ensure that public sector accounting practices are carried out in compliance with standards, financial services experts and internal auditors need to receive more comprehensive training on IPSAS and EPSAS.

Enhancing Budget-Accounting Integration: Efforts should be made to harmonize accrual-based budgeting and reporting systems more effectively in public accounting.

Conducting Pre-Analysis for the EPSAS Transition Process: The potential financial and administrative changes that may arise during Türkiye's transition to EPSAS should be identified in advance, and necessary regulatory arrangements should be planned.

In conclusion, adapting Türkiye's IPSAS-compliant public accounting system to EPSAS will integrate public financial management more closely with international standards in the long term. However, to achieve this, the necessary institutional and legal regulations must be made to address the challenges encountered during the process.

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Uncovering the Interactions Among Barriers to Sustainable Supply Chain Management: Insights From Kerala's Leading Textile Manufacturing Industries

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This study explores barriers to Sustainable Supply Chain Management (SSCM) in Kerala's textile manufacturing sector using the ISM-MICMAC approach. It identifies and analyzes ten key barriers: lack of clear policies, financial constraints, poor supplier performance, inadequate infrastructure, high implementation costs, insufficient training, low stakeholder commitment, regulatory challenges, technological limitations, and unfavorable supplier attitudes. Among these, "lack of clear policies and practices" emerges as the most influential root-cause barrier, driving systemic inefficiencies. The findings offer a structured framework for policymakers and industry stakeholders to develop effective SSCM strategies, enhancing operational efficiency and fostering a more sustainable and resilient textile supply chain.

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1 Introduction

The textile and apparel industries are vital to the global economy, contributing to employment, trade, and technological advancement. In India, this sector accounts for 2% of the GDP and 12% of export revenue, employing approximately 45 million people across organized and unorganized segments. In Kerala, it plays a key role in regional development and job creation. However, the textile industry is the world's second-largest polluter, generating greenhouse gas emissions, toxic wastewater, and excessive waste, highlighting the urgent need for Sustainable Supply Chain Management (SSCM) practices.

SSCM aims to reduce environmental impact while enhancing social and economic performance. Despite significant investments in quality and innovation, Kerala's textile manufacturers face barriers to SSCM adoption, including poor stakeholder communication, limited awareness of green practices, reliance on conventional technologies, inadequate reverse logistics, and insufficient infrastructure. These challenges hinder alignment with global sustainability standards and the transition to a circular economy.

While existing research identifies barriers like communication gaps, lack of advanced technology, inadequate training, and poor waste management through methodologies such as Interpretive Structural Modelling (ISM), MICMAC, and DEMATEL, most studies focus on macro-level insights in industrialized regions. There is limited research on how these barriers interconnect in Kerala's smaller-scale, labor-intensive textile sector.

This study identifies key barriers to Sustainable Supply Chain Management (SSCM) in Kerala's textile manufacturing industry, offering actionable insights to foster sustainable practices. Given Kerala's commitment to environmental preservation, it addresses the region's unique infrastructural and systemic challenges. Using the ISM methodology, it identifies, and categorizes the barriers while mapping their interdependencies.

For manufacturers, the study provides a framework to prioritize barriers, aiding resource allocation and decision-making. Policymakers can use these insights to design targeted interventions like capacity-building initiatives and infrastructure

improvements. Addressing challenges such as communication gaps, outdated technologies, and limited reverse logistics can enhance the region's sustainable supply chain ecosystem. Academically, the study contributes to SSCM literature through a region-specific case study bridging theory with practice. Using Interpretive Structural Modelling (ISM), it analyzes interdependencies among barriers, offering insights applicable to both academic research and industry.

The findings contribute region-specific insights to the SSCM literature and offer practical recommendations for industry leaders, policymakers, and stakeholders. This research aims to guide Kerala's textile firms in adopting sustainable practices, improving competitiveness, and reducing environmental impact. By analyzing SSCM barriers and their interdependencies, the study provides a clear roadmap for transforming Kerala's textile industry into a more sustainable and responsible sector.

2 Literature review

The integration of Artificial Intelligence (AI) in the textile industry is driving significant advancements in manufacturing, design, quality control, and sustainability (Kumar et al., 2024). In India, AI adoption has led to improved manufacturing efficiency, increased worker productivity, and reduced product development lead times (Reenu et al., 2024). Moreover, AI plays a crucial role in enhancing Environmental, Social, and Governance (ESG) reporting for organizations, particularly Micro, Small, and Medium Enterprises (MSMEs) in India (Kulkarni et al., 2023). These developments collectively contribute to the evolution of sustainable supply chain management (SSCM) by promoting resource optimization, minimizing environmental impact, ensuring compliance with ESG standards, and fostering transparency and traceability across the value chain. By embedding AI into supply chain processes, the textile industry is better equipped to align with global sustainability goals and build more resilient, responsible supply networks.

Sustainable supply chain management (SSCM) integrates social and environmental considerations into conventional supply chain management, extending its focus beyond economic aspects (Seuring & Müller, 2008). Key drivers for SSCM adoption include consumer demand for ethically sourced products, growing environmental awareness, and regulatory pressures, particularly in resource-intensive industries like textiles (Carter & Rogers, 2008). SSCM aims to reduce the environmental and social

impacts of supply chains through green technologies, waste reduction, ethical labor practices, and sustainable procurement (Ahi & Searcy, 2013). The textile industry, known for its significant carbon footprint, water consumption, and chemical waste, produces over 1.2 billion tonnes of CO2 equivalent annually (Allwood et al., 2006). Sustainable practices in this sector are crucial for legal compliance, enhancing corporate social responsibility (CSR) profiles, reducing environmental impact, and improving long-term competitiveness.

Implementing SSCM strategies in the textile sector faces substantial challenges, primarily financial constraints. Investments in green technologies and sustainable raw materials are capital-intensive, particularly for small and medium-sized enterprises (SMEs), which dominate textile manufacturing (Harris et al., 2002). Many firms, especially in developing countries, struggle to secure funding for initiatives with delayed financial returns (Seuring & Müller, 2008). High upfront costs discourage long-term investments in sustainable technologies (Gunasekaran et al., 2015). Additionally, disposing of hazardous waste incurs significant expenses, particularly in textile finishing and dyeing processes (Srivastava, 2007). The lack of recycling facilities and high environmental compliance costs further burden firms (Govindan et al., 2015). Textile industries in regions like Kerala face difficulties meeting stringent environmental standards due to the high costs of waste management.

Infrastructure deficiencies further impede SSCM implementation. Limited recycling and waste disposal infrastructure restrict sustainable supply chain practices (Sarkis et al., 2011). Kerala's textile industry, for instance, requires advanced recycling facilities to adopt a circular economy model. Inadequate infrastructure hampers effective waste treatment, resulting in resource inefficiencies and environmental harm. Moreover, the limited market for recycled materials poses additional challenges. Textile companies struggle to find buyers for recovered materials, discouraging investment in recycling initiatives (Govindan et al., 2015). A lack of skilled personnel and training on sustainable practices exacerbates these issues, as businesses face difficulties implementing and managing sustainability initiatives (Ageron et al., 2012). Insufficient internal and external support within supply chains further limits SSCM adoption (Kumar & Saini, 2017).

Various barriers to SSCM implementation identified in the literature were explored and are presented in the table below.

Table 1: Barriers in SSCM implementation

Sl. No	Barrier name	Description	Reference
1	Lack of government initiatives	Lack of support and commitment from top management limits SSCM initiatives.	Tayet al. (2015), Govindan et al. (2014), Luthra et al. (2011)
2	Poor organizational structure	Inefficient organizational structure hinders smooth implementation of SSCM.	Mathiyazhagan et al. (2013), Muduli et al. (2013), Luthra et al. (2011)
3	Lack of commitment by top level management	Lack of support and commitment from top management limits SSCM initiatives.	Tayet al. (2015), Govindan et al. (2014), Muduli et al. (2013)
4	High initial cost of implementation	Significant initial investment required for SSCM implementation can be a deterrent.	Govindan et al. (2014), Zhu and Geng (2013), Mathiyazhagan et al. (2013),
5	Lack of policies and practices for the retention of skilled and experienced employees in the organization	Difficulty in retaining skilled and experienced employees hampers SSCM implementation.	Mathiyazhagan et al. (2013), Muduli et al. (2013)
6	Lack of proper rewards and acceptance from the government	Inadequate government support and incentives can discourage SSCM adoption.	Mathiyazhagan et al. (2013), Luthra et al. (2011), Faisal (2010)
7	Lack of knowledge and training in SSCM	Insufficient knowledge and training among employees can hinder effective SSCM implementation.	Govindan et al. (2014), Mathiyazhagan et al. (2013)
8	Lack of monitoring and control	Absence of proper monitoring and control mechanisms can lead to deviations from SSCM goals.	Govindan et al. (2014), Zhu and Geng (2013), Muduli et al. (2013)
9	Fear of failure	Fear of failure can discourage organizations from taking risks and adopting innovative SSCM practices.	Govindan et al. (2014), JMTM 30,6 Mathiyazhagan et al. (2013),
10	Lack of clear policies and practices	Ambiguous policies and practices can hinder effective SSCM implementation.	Muduli et al. (2013), Ravi and Shankar (2005)
11	Lack of budget for SSCM implementation	Insufficient budget allocation can limit the scope and effectiveness of SSCM initiatives.	Govindan et al. (2014), Faisal (2010)

Sl. No	Barrier name	Description	Reference
12	Inconsistent and inadequate performance measures	Lack of clear and consistent performance measures can hinder evaluation and improvement of SSCM practices.	Tayet al. (2015), Govindan et al. (2014)
13	Complexity of design to reuse/recycle the used products	Complex product design can increase the cost and difficulty of recycling and reuse.	Govindan et al. (2014), Mathiyazhagan et al. (2013) Bhanot et al. (2015), Luthra et al. (2015)
14	Lack of benchmark in India	Absence of industry benchmarks can make it challenging to measure and improve SSCM performance.	Zhu and Geng (2013), Faisal (2010), Ravi and Shankar (2005)
15	Lack of supply chain support	Lack of cooperation and support from supply chain partners can hinder the implementation of sustainable practices.	Faisal (2010), Ravi and Shankar (2005)
16	Lack of markets for recycled materials	Limited demand for recycled materials can discourage recycling efforts.	Govindan et al. (2014), Faisal (2010)
17	Lack of infrastructure facilities for SSCM implementation	Lack of adequate infrastructure can hinder the implementation of SSCM initiatives.	Govindan et al. (2014), Muduli et al. (2013)
18	Lack of motivation in adopting SSCM	Lack of motivation and awareness among employees can hinder the adoption of SSCM practices.	Muduli et al. (2013), Faisal (2010)
19	Lack of strategic planning	Absence of a clear strategic plan can limit the effectiveness of SSCM initiatives.	Mathiyazhagan et al. (2013), Muduli et al. (2013), Luthra et al. (2011),
20	Lack of experts in providing expert opinion about sustainable practices	Difficulty in accessing expert advice can hinder the implementation of sustainable practices	Govindan et al. (2014), Mathiyazhagan et al. (2013)
21	Negative attitude of suppliers toward supplying sustainable raw materials	Resistance from suppliers to supply sustainable materials can limit the adoption of sustainable sourcing practices.	Mathiyazhagan et al. (2013), Zhu and Geng (2013), Faisal (2010)
22	Lack of mutual trust among the supply chain members	Lack of trust among supply chain partners can hinder collaboration and information sharing.	Tayet al. (2015), Govindan et al. (2014), Luthra et al. (2011)
23	Lack of supply chain partners' performance	Poor performance of supply chain partners can negatively impact the overall	Bhanot et al. (2015), Govindan et al. (2014),

Sl. No	Barrier name	Description	Reference
		sustainability performance of the organization.	Mathiyazhagan et al. (2013)
24	High cost of hazardous waste disposal	High disposal costs can discourage the adoption of sustainable waste management practices.	Govindan et al. (2014), Mathiyazhagan et al. (2013)
25	Lack of new technology, materials and processes	Limited availability of new technologies and materials can hinder the development of sustainable solutions.	Muduli et al. (2013)
26	Resistance to change due to fear of unemployment	Fear of job loss can lead to resistance to change and hinder the adoption of new sustainable practices.	Tayet al. (2015), Govindan et al. (2014), Luthra et al. (2011)
27	Distraction or slowdown due to existing projects	Ongoing projects can divert resources and attention away from SSCM initiatives.	Faisal (2010), Ravi and Shankar (2005)
28	Unclear understanding of economic benefit	Lack of clarity regarding the economic benefits of SSCM can discourage investment in sustainable practices.	Muduli et al. (2013), Ravi and Shankar (2005)
29	Frequent changes in managerial body	Frequent changes in management can disrupt the continuity of SSCM initiatives.	Muduli et al. (2013), Ravi and Shankar (2005)

Methodologies such as Interpretive Structural Modelling (ISM) and MICMAC analysis are valuable for understanding and addressing SSCM challenges. ISM, developed by Warfield (1974), identifies relationships between system components and arranges them hierarchically based on their interdependencies. This method is effective for analyzing SSCM barriers, revealing how financial constraints and implementation costs cascade into other issues like supplier collaboration and infrastructure deficits (Ahi & Searcy, 2013). MICMAC analysis (Cross-impact matrix multiplication applied to classification) complements ISM by mapping driving and dependent barriers, clarifying their mutual influence (Saaty, 2005). For instance, inadequate recycling infrastructure may depend on government policies and financial support. These methodologies enable firms to prioritize interventions that address multiple barriers simultaneously, enhancing SSCM effectiveness (Seuring & Müller, 2008; Bai & Sarkis, 2014).

Kerala's textile sector faces unique SSCM challenges, including regulatory gaps and supplier resistance. Unlike regions with well-defined sustainability mandates and incentives, Kerala lacks a robust regulatory framework, creating uncertainty and

discouraging investment in sustainable practices (Govindan et al., 2015). Supplier reluctance to provide sustainable raw materials is another critical issue. Many textile manufacturers struggle to find reliable, cost-effective sources of sustainable materials due to low demand and concerns about increased production costs (Kumar & Saini, 2017). Small local suppliers, lacking resources to adopt sustainable processes, further compound this problem. Despite these challenges, some textile firms in Kerala have implemented waste reduction measures and prioritized eco-friendly raw materials, aligning with global sustainability trends. However, persistent financial and infrastructural barriers continue to hinder broader adoption.

Tools like ISM and MICMAC provide a structured approach to identifying and prioritizing SSCM barriers in the textile industry. By mapping interdependencies and addressing primary obstacles, firms can enhance supply chain sustainability and competitiveness. Successful SSCM adoption requires comprehensive strategies involving financial investment, infrastructure development, and collaborative efforts across the supply chain.

3 Methodology

This study adopts a mixed-methods approach to examine barriers to sustainable supply chain management (SSCM) in Kerala's textile manufacturing industry. Semi-structured interviews were conducted with five supply chain managers from different textile manufacturing firms, and secondary data was gathered through a literature review. Data analysis involved identifying barriers, developing a Structural Self-Interaction Matrix (SSIM), and applying Interpretive Structural Modelling (ISM) and MICMAC analysis to explore barrier interconnections, root causes, and key drivers affecting SSCM adoption. An Overview of research methodology is presented in figure 1.

Figure 1: Overview of research methodology

Step 1: Identification of Barriers

The research began with a comprehensive literature review to identify potential barriers to sustainable supply chain management (SSCM) in Kerala's textile manufacturing industry. This involved analyzing previous research papers, publications, and reports to identify common challenges within related academic domains. Through this process, a preliminary list of 29 potential barriers was compiled as presented in table 1.

Step 2: Barrier Shortlisting

The initial list of 29 barriers was refined through expert consultation. Semi-structured interviews were conducted with five supply chain managers from various textile manufacturing firms to gather insights on the most critical barriers. This process resulted in a shortlist of 10 key barriers for further analysis. The 10 key barriers are presented below.

B1: High initial cost of implementation
B2: Lack of knowledge and training in SSCM
B3: Lack of budget for SSCM implementation
B4: Lack of infrastructure facilities for SSCM implementation
B5: Lack of supply chain support

B6: Lack of markets for recycled materials
B7: Lack of clear policies and practices
B8: Negative attitude of suppliers toward supplying sustainable raw materials
B9: Lack of supply chain partners' performance
B10: High cost of hazardous waste disposal

Step 3: Structure in Hierarchy

The 10 shortlisted barriers were organized hierarchically using the Interpretive Structural Modelling (ISM) technique. This method helped map the relationships and interdependencies among the barriers, providing a clear visualization of how they influence one another. The ISM framework highlighted the most influential barriers and their root causes, offering a structured understanding of the problem. The various stages of ISM and MICMAC approach is presented in figure 2.

Step 4: Barrier Classification

The Matrix of Cross-Impact Multiplications Applied to Classification (MICMAC) analysis was employed to categorize the barriers based on their driving and dependence power. Each barrier was classified into one of four categories:

- **Independent Barriers:** High driving power and low dependence power.
- **Dependent Barriers:** High dependence power and low driving power.
- **Linkage Barriers:** Moderate driving and dependence power, indicating mutual influence.
- **Autonomous Barriers:** Low driving and dependence power, having minimal influence.

This classification provided deeper insights into the dynamic relationships between barriers and their influence on SSCM practices.

Interpretive structural model

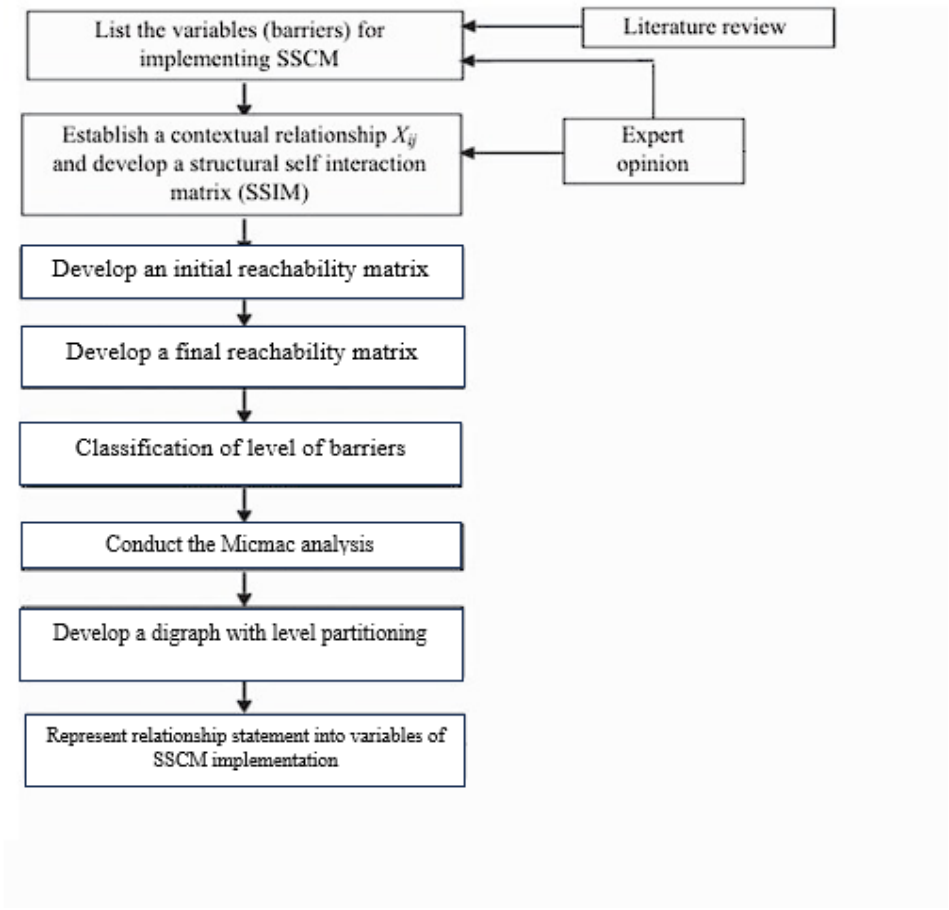

Figure 2: Stages of ISM MICMAC Approach

With reference to the textile manufacturing sector under investigation, this research study aims to identify and analyze the barriers to Sustainable Supply Chain Management (SSCM) implementation in Kerala's textile industry. Addressing these challenges is crucial for fostering sustainable practices within the region's supply networks. The research employs the Interpretive Structural Modeling (ISM) methodology to develop a structured framework for categorizing and ranking the primary obstacles to information exchange. This framework provides decision-

makers with a systematic approach to address these barriers and lays the foundation for achieving long-term sustainable growth in the supply chain.

This kind of problem formulation is particularly well-suited for the ISM approach, which relies on expert opinions to analyze complex relationships. For this study, opinions were gathered from five specialists, each possessing extensive knowledge and expertise in SSCM and the textile industry. Their insights play a critical role in identifying and analyzing the interdependencies among barriers. The relationships between these barriers are depicted using the "i" and "j" notation to indicate directionality and influence.

A Structural Self-Interaction Matrix (SSIM) of order 10 × 10 was constructed based on the contextual relationships between the identified barriers. This matrix was populated using the expert panel's evaluations, with each symbol reflecting the direct relationship between barriers. The symbols used in the SSIM are defined as follows:

The relationships between the barriers are represented using the following symbols:

- **V** = Barrier 'i' influences barrier 'j'.
- **A** = Barrier 'j' influences barrier 'i'.
- **X** = Barrier 'i' and 'j' influence each other.
- **O** = Barrier 'i' and 'j' are unrelated.

The identified barriers and their corresponding codes are as follows:

- **B1:** High initial cost of implementation
- **B2:** Lack of knowledge and training in SSCM
- **B3:** Lack of budget for SSCM implementation
- **B4:** Lack of infrastructure facilities for SSCM implementation
- **B5:** Lack of supply chain support
- **B6:** Limited markets for recycled materials
- **B7:** Absence of clear policies and practices
- **B8:** Negative attitude of suppliers toward providing sustainable raw materials

- **B9:** Inadequate performance of supply chain partners
- **B10:** High cost of hazardous waste disposal

Structural Self-Interaction Matrix (SSIM)

The Structural Self-Interaction Matrix (SSIM) evaluates the relationships among ten key obstacles to implementing Sustainable Supply Chain Management (SSCM). Using symbols such as V, A, X, and O, the matrix illustrates how each barrier influences or interacts with others. This analytical tool helps identify the primary barriers and their interdependencies, providing a foundation for further investigation.

Table 2: Structural self-interaction matrix

Structural Self-Interaction Matrix (SSIM)

Variables	1	2	3	4	5	6	7	8	9	10
High initial cost of implementation		A	O	A	A	O	A	V	A	O
Lack of knowledge and training in SSCM			A	V	V	V	A	V	V	V
Lack of budget for SSCM implementation				V	V	V	A	O	V	O
Lack of infrastructure facilities for SSCM implementation					V	A	A	V	V	V
Lack of supply chain support						A	A	A	V	V
Lack of markets for recycled materials							A	A	A	O
Lack of clear policies and practices								V	V	V
Negative attitude of suppliers toward supplying sustainable raw materials									A	O
Lack of supply chain partners' performance										V
High cost of hazardous waste disposal										

Formation of Initial Reachability Matrix (IRM)

Following the development of the Structural Self-Interaction Matrix (SSIM), the next step in the Interpretive Structural Modeling (ISM) approach involves constructing the initial Reachability Matrix (RM). This matrix quantifies the relationships between the ten identified barriers to implementing Sustainable Supply Chain Management (SSCM). It is derived by converting the symbolic representations from the SSIM into binary values: '1' indicates the presence of a relationship where one barrier influences another, while '0' signifies no direct relationship.

Table 3: Reachability Matrix (RM)

Reachability Matrix(RM)

Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
High initial cost of implementation	1	0	0	0	0	0	0	1	0	0	2
Lack of knowledge and training in SSCM	1	1	0	1	1	1	0	1	1	1	8
Lack of budget for SSCM implementation	0	1	1	1	1	1	0	0	1	0	6
Lack of infrastructure facilities for SSCM implementation	1	0	0	1	1	0	0	1	1	1	6
Lack of supply chain support	1	0	0	0	1	0	0	0	1	1	4
Lack of markets for recycled materials	0	0	0	1	1	1	0	0	0	0	3
Lack of clear policies and practices	1	1	1	1	1	1	1	1	1	1	10
Negative attitude of suppliers toward supplying sustainable raw materials	0	0	0	0	1	1	0	1	0	0	3
Lack of supply chain partners' performance	1	0	0	0	0	1	0	1	1	1	5
High cost of hazardous waste disposal	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	6	3	2	5	7	6	1	6	6	6	

The RM is populated systematically: the upper diagonal elements are filled directly from the SSIM, while the lower diagonal elements are derived using the fundamental steps of the ISM process, which account for both forward and backward relationships. This comprehensive approach ensures a complete representation of barrier interdependencies.

Two critical measures are derived from the RM: Driving Power and Dependence Power. Driving Power, displayed in the last column, reflects the extent to which a barrier influences other barriers. Dependence Power, shown in the bottom row, indicates the total influence a barrier receives from others. For instance, the barrier "Absence of clear policies and practices" exhibits the highest Driving Power (10), signifying its substantial impact on all other barriers.

The Reachability Matrix is a crucial tool in the ISM methodology as it helps identify key drivers and dependent barriers. By analyzing these relationships, decision-makers can prioritize actions to address the most influential obstacles, facilitating a more effective and strategic approach to overcoming SSCM implementation challenges.

Final Reachability Matrix (FRM)

To obtain the Final Reachability Matrix (FRM), the Initial Reachability Matrix (IRM) is further refined through an iterative process based on the dependency relationships. This step is crucial for capturing transitive relationships, where the influence of one barrier on another extends through intermediate variables.

The FRM provides a comprehensive view of the interconnections among the ten barriers to implementing Sustainable Supply Chain Management (SSCM) practices. In the matrix, a direct relationship between barriers is represented by '1,' while a transitive (indirect) relationship is denoted by '1.' This enhanced matrix reveals both immediate and extended influences, offering deeper insights into barrier interdependencies *.

Table 4: Final Reachability Matrix (FRM)

Final Reachability Matrix(FRM)

Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
High initial cost of implementation	1	0	0	1*	1*	1*	0	1	1*	1*	7
Lack of knowledge and training in SSCM	1	1	0	1	1	1	0	1	1	1	8
Lack of budget for SSCM implementation	1*	1	1	1	1	1	0	1*	1	1*	9
Lack of infrastructure facilities for SSCM implementation	1	0	0	1	1	1*	0	1	1	1	7
Lack of supply chain support	1	0	0	1*	1	1*	0	1*	1	1	7
Lack of markets for recycled materials	1*	0	0	1	1	1	0	1*	1*	1*	7
Lack of clear policies and practices	1	1	1	1	1	1	1	1	1	1	10
Negative attitude of suppliers toward supplying sustainable raw materials	1*	0	0	1*	1	1	0	1	1*	1*	7
Lack of supply chain partners' performance	1	0	0	1*	1*	1	0	1	1	1	7
High cost of hazardous waste disposal	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	9	3	2	9	9	9	1	9	9	10	

Among the identified barriers, the "Absence of clear policies and practices" exhibits the highest Driving Power (10), indicating that it is a primary root cause affecting all other barriers. The Driving Power, presented in the column 12 of table 4, reflects the number of barriers influenced by a specific variable. Conversely, the Dependence Power, shown in the row 11 of table 4, indicates how strongly each barrier is affected by others.

By distinguishing between key drivers and dependent obstacles, the FRM enables decision-makers to prioritize efforts for addressing SSCM challenges. This systematic identification of critical barriers provides a strategic framework for overcoming implementation difficulties and facilitating sustainable supply chain practices.

Classification of levels of barriers

Following the computation of each barrier's cumulative score for Driving Power and Dependence Power, the next step involves assigning hierarchical levels to the identified barriers. This process is crucial for understanding the structural relationships and influence pathways among the barriers.

The level identification process begins by determining the *Reachability Set* and the *Antecedent Set* for each barrier. The Reachability Set includes the barrier itself and all other barriers it influences. Conversely, the Antecedent Set consists of the barrier itself and all barriers that affect it. The *Intersection Set* is derived by identifying the common elements shared between the Reachability and Antecedent Sets.

A barrier is assigned a specific level if its Reachability Set exactly matches its Intersection Set. Once a level is determined, the corresponding barrier is removed from further consideration. This iterative process continues until all barriers are categorized into distinct hierarchical levels.

This systematic classification aids in understanding the relative influence of each barrier, distinguishing between foundational barriers (drivers) and those that are dependent. Such insights are critical for developing targeted strategies to overcome obstacles and facilitate the successful implementation of Sustainable Supply Chain Management (SSCM) practices.

Table 5: Level Partitioning

Level Partitioning(LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
2	2,	2, 3, 7,	2,	3
3	3,	3, 7,	3,	4
4	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
5	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
6	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
7	7,	7,	7,	5
8	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
9	1, 4, 5, 6, 8, 9,	1, 2, 3, 4, 5, 6, 7, 8, 9,	1, 4, 5, 6, 8, 9,	2
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	10,	1

Digraph

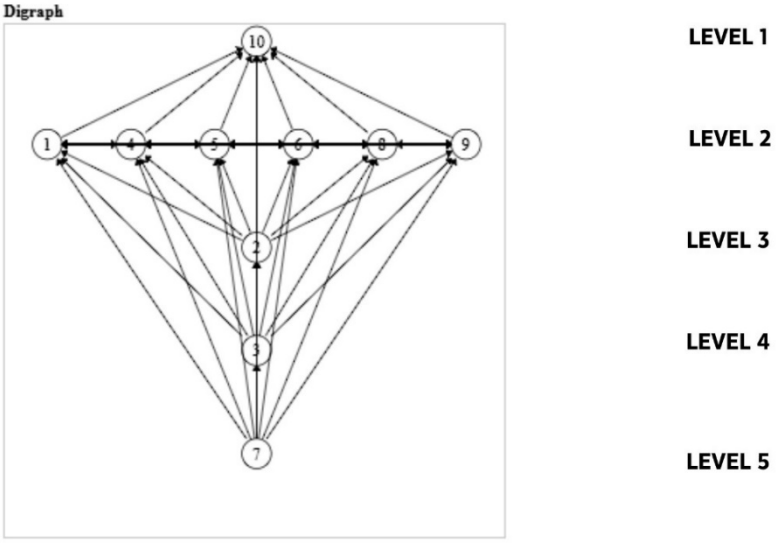

Figure 3: Digraph

A directed graph (Digraph) visually represents the hierarchical structure of a system by using nodes to denote components or variables and directed arrows to indicate relationships of influence or dependence. Each node in the graph is numbered (e.g., 1, 2, 3,…, 10) to correspond to a specific system component. The nodes are systematically arranged into five hierarchical levels based on the level partitioning presented in table 5, reflecting their relative influence and dependence. The digraph is presented in figure 3.

In the digraph, Node 10 is positioned at the top (Level 1) as the primary driver, exerting influence on other barriers. Level 2 comprises Nodes 1, 4, 5, 6, 8, and 9, which are directly influenced by Node 10 and, in turn, affect subsequent levels. Node 2 is located at Level 3, Node 3 at Level 4, and Node 7, the most dependent node, is positioned at the bottom (Level 5). As the hierarchy descends, nodes at higher levels exert influence on those below them, as indicated by the direction of the arrows. For instance, arrows extending from Level 2 to Levels 3, 4, and 5 depict the interdependencies among these components.

This graphical representation provides a clear and systematic visualization of the relationships within the system, distinguishing key drivers from dependent variables. Node 10, with its multiple outgoing arrows, represents the most influential barrier, while Node 7, influenced by all preceding levels, is the most dependent.

The Interpretive structural model presented in table 4 reveal that the "lack of clear policies and practices" is the primary barrier to adopting sustainable supply chain management (SSCM) and serves as the root cause of all other barriers. Ambiguous policies create confusion and a lack of direction for stakeholders, leading to insufficient "budget allocation for SSCM implementation." Without proper budgeting, businesses face challenges in funding critical areas such as infrastructure development, information sharing, and employee training. As a result, the "lack of knowledge and training in SSCM" leaves employees and supply chain partners ill-equipped to adopt and effectively implement sustainable practices.

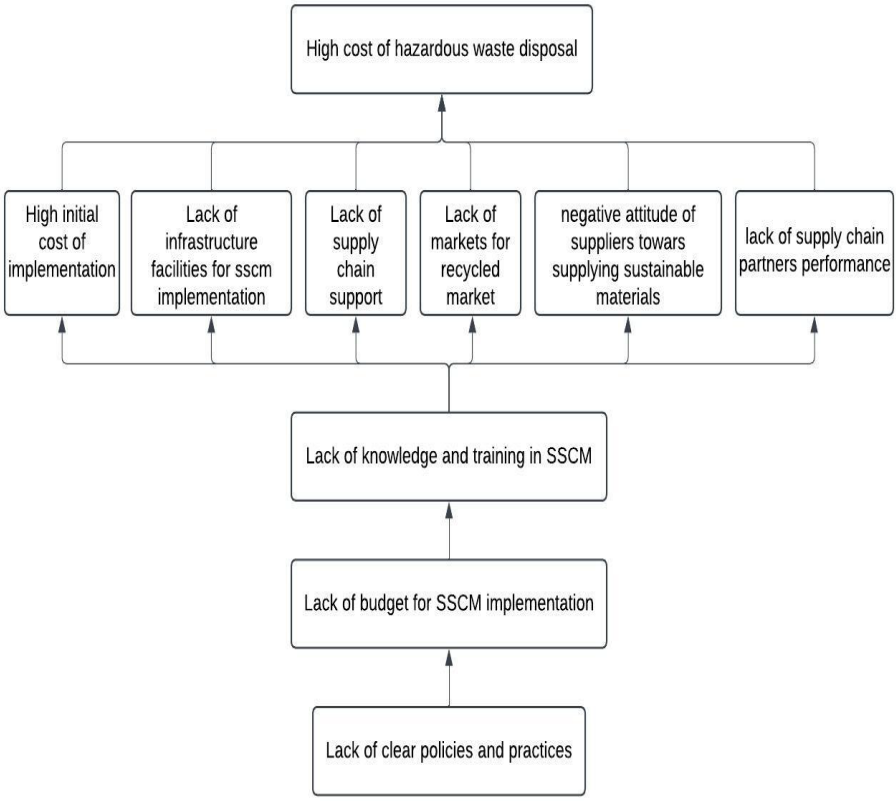

Figure 4: Interpretive structural model

The absence of clear policies also contributes to increased costs and inefficiencies, further amplifying barriers like the "high initial implementation costs." Without structured guidelines, companies resort to inconsistent and ineffective practices, driving up expenses. Similarly, policy frameworks play a crucial role in directing infrastructure investments. In their absence, organizations experience a "lack of infrastructure facilities for SSCM implementation," which hinders the seamless adoption of sustainable practices.

Moreover, the "lack of markets for recycled materials" and the "negative attitudes of suppliers toward sustainable materials" stem from the absence of clear regulations and incentives that would otherwise encourage sustainable practices. Fragmented

responsibilities and poor coordination—caused by unclear policies—further worsen the "poor performance of supply chain partners."

By addressing the "lack of clear policies and practices," these interconnected barriers can be systematically mitigated. In the textile industry, resolving this root cause will facilitate a more efficient and sustainable supply chain, fostering long-term environmental and operational benefits.

MICMAC analysis

MICMAC (Matrix of Cross-Impact Multiplication Applied to a Classification) analysis is a strategic method used to examine the interconnections between various elements or barriers within a system. It categorizes variables based on their driving and dependence power, helping to identify the primary drivers and dependent factors that influence a particular system. MICMAC analysis is especially valuable in complex systems such as Sustainable Supply Chain Management (SSCM), where numerous interrelated obstacles make it challenging to prioritize and manage them effectively.

MICMAC analysis categorizes barriers into four groups:

1. Drivers – Variables with high driving power and low dependence, which act as the root causes influencing other barriers.
2. Dependent Variables – Variables with low driving power and high dependence, which are outcomes influenced by other factors.
3. Linkage Variables – Variables with both high driving and dependence power, which are highly interconnected and sensitive to changes.
4. Independent Variables – Variables with low driving and dependence power, which are weakly connected to the system.

The MICMAC analysis is visually represented through a graph - figure 5, where the X-axis (horizontal) indicates the Dependence Power of the variables, ranging from left to right (0 to 10), and the Y-axis (vertical) represents the Driving Power, ranging from bottom to top (0 to 10). This graphical representation divides the variables into the four quadrants, providing a clear depiction of their influence and interdependencies within the SSCM system. Using data from the Final Reachability

Matrix (FRM) presented in Table 4, MICMAC analysis classifies the ten barriers to SSCM implementation according to their driving and dependence power. For instance, the barrier "Lack of clear policies and practices" exhibits the highest driving power (10), significantly influencing other barriers. Conversely, barriers such as the "High cost of hazardous waste disposal," which exhibit low driving and dependence power, may not directly influence other barriers but still warrant attention.

The numbered dots on the graph represent specific variables. For instance, variables 1, 4, 5, 6, 8, and 9 fall within Quadrant III (Linkage Variables), highlighting their dual role as both influencers and dependents. Variables 2 and 3, located in Quadrant IV (Independent Variables), demonstrate strong driving power with minimal dependence on others. Variable 7, positioned near the top of the graph, exhibits the highest driving power and the lowest dependence, making it a critical driver. Conversely, variables in Quadrant I are considered less influential within the system.

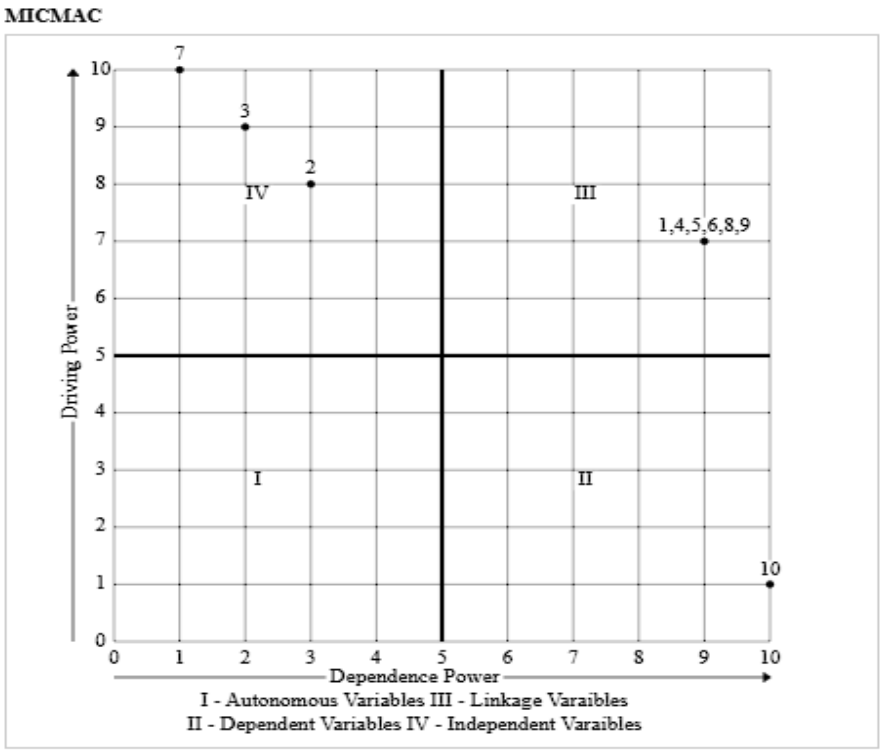

Figure 5: MICMAC graph

The MICMAC classification provides a systematic understanding of how different barriers interact, helping prioritize efforts to address the most impactful challenges in Sustainable Supply Chain Management (SSCM).

4 Results and discussion

The findings of this study provide a comprehensive understanding of the barriers to implementing Sustainable Supply Chain Management (SSCM) in Kerala's textile manufacturing sector through the application of the ISM-MICMAC approach. By systematically analyzing the interrelationships between these barriers, the study identifies the "lack of clear policies and practices" as the root cause barrier with the highest driving power and minimal dependency. This insight emphasizes the fundamental role of policy frameworks in shaping the adoption of SSCM practices and suggests that addressing this core barrier can create a cascading effect to mitigate other challenges.

A key implication of the study is that without clear SSCM policies, organizations face ambiguity in resource allocation, investment planning, and stakeholder engagement. This ambiguity not only inhibits the establishment of structured sustainability initiatives but also exacerbates downstream challenges such as insufficient infrastructure and budget constraints. The lack of policy direction reduces the incentive for organizations to invest in training programs and collaborate with supply chain partners, thereby limiting the overall effectiveness of SSCM implementation. This finding aligns with previous literature emphasizing the role of regulatory frameworks in facilitating sustainable practices and suggests that policymakers should prioritize the development of comprehensive SSCM guidelines to provide a clear roadmap for industry stakeholders.

The study further highlights the role of connecting barriers, including high initial implementation costs, inadequate infrastructure, and unfavorable supplier attitudes. These barriers exhibit both high driving and dependency power, indicating their pivotal position in sustaining or alleviating systemic challenges. High initial costs remain a persistent obstacle, particularly for small and medium-sized enterprises (SMEs), due to the substantial financial burden associated with adopting sustainable technologies, improving waste management systems, and providing personnel training. Addressing these barriers requires coordinated action through public-

private partnerships to subsidize infrastructure development and provide financial incentives for sustainable investments.

The MICMAC analysis reveals that the "high cost of hazardous waste disposal" functions as a dependent barrier with minimal driving power. This indicates that waste management costs are largely symptomatic of upstream inefficiencies, such as the absence of clear policies and limited financial support. This finding underscores the need to address structural and policy-level issues to alleviate the financial burden of hazardous waste disposal. Establishing well-defined waste management regulations and providing economic incentives for waste reduction could help mitigate these dependent barriers and promote a circular economy within the textile sector.

Another critical insight from the study is the influence of knowledge gaps on SSCM implementation. Insufficient training and awareness hinder the ability of employees and supply chain partners to engage with sustainable practices effectively. This suggests that developing targeted education programs and conducting awareness campaigns are essential to bridge these gaps. By enhancing stakeholder knowledge, organizations can facilitate better decision-making, improve compliance with environmental standards, and foster a culture of sustainability.

The study's findings also point to the necessity of fostering collaboration across the supply chain to overcome resistance from suppliers and ensure cohesive implementation of SSCM practices. Supplier reluctance often stems from concerns about increased operational costs and market uncertainty for sustainable products. Therefore, improving supplier engagement through collaborative platforms, joint sustainability initiatives, and long-term contractual agreements can mitigate resistance and align incentives.

In summary, the ISM-MICMAC approach provides a structured framework to identify and prioritize the most influential barriers to SSCM adoption. The study emphasizes that addressing root-cause barriers, particularly the lack of clear policies, is paramount for fostering sustainable practices. Complementary measures such as infrastructure investment, financial support, and comprehensive training programs are also critical to overcoming connecting and dependent barriers. By implementing these strategies, the textile manufacturing sector in Kerala can achieve more effective

and sustainable supply chain management while advancing broader environmental and economic goals.

5 Conclusions

This study underscores the critical role of clear policies and practices in facilitating the adoption of Sustainable Supply Chain Management (SSCM) within Kerala's textile manufacturing sector. Among the eleven identified barriers, the "lack of clear policies and practices" emerged as the most influential driving factor. Addressing this foundational issue is essential, as unclear policies lead to systemic inefficiencies, including inadequate infrastructure investments, insufficient training initiatives, and poor budget allocation. These inefficiencies amplify the high upfront implementation costs and diminish the overall performance of supply chain participants.

The ISM-MICMAC analysis further revealed several key connecting barriers, such as high implementation costs, inadequate infrastructure, hostile supplier attitudes, and subpar supply chain partner performance. These barriers exhibit both significant driving and dependency powers, acting as intermediaries that propagate challenges across the supply chain. Overcoming these linking barriers requires a comprehensive and coordinated strategy involving active stakeholder engagement, legislative reforms, and targeted infrastructure investments.

A particularly noteworthy finding is that the "high cost of hazardous waste disposal" functions as a dependent variable with low driving power. This barrier is largely a consequence of upstream inefficiencies, highlighting the importance of addressing root causes and intermediary obstacles to mitigate its impact.

To successfully implement SSCM, the study emphasizes the necessity of establishing well-defined and enforceable policies. Clear guidelines provide a structured framework that facilitates sustainable practices, optimizes resource allocation, modernizes infrastructure, and fosters greater supplier participation. Additionally, targeted initiatives such as awareness campaigns, capacity-building programs, and the expansion of markets for sustainable products are crucial in addressing the connecting barriers.

By adopting a holistic and strategic approach, Kerala's textile industry can effectively navigate the complexities of SSCM implementation and advance toward achieving long-term sustainability goals. The insights from this research offer a valuable foundation for future studies and practical interventions in sustainable supply chain management, providing a roadmap for industries seeking to enhance sustainability within their operations.

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DIVERSITY, EQUITY, AND INCLUSION – A CASE OF SELECT INDIAN ORGANIZATIONS

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Internationally, companies have made DEI metrics a Key Performance Indicator (KPI) and have linked executive compensation to their direct contributions. With the recent changes, due to the anti-DEI executive orders and increasing legal and political challenges, facing such initiatives of the United States of America (USA), the Diversity, Equity, and Inclusion (DEI) programs all across the globe are disrupted. Though there are studies in DEI programs, policies, and initiatives in various sectors and policy levels, very little study is done on investments. Hence, this study proposes a unique approach regarding the DEI perspectives and relevant investment policy decisions. Nifty 50, an Indian stock market Index representing the performance of the 50 largest Indian companies listed as of 17th March 2025, in the National Stock Exchange (NSE), is the sample framework from which the sample of organizations was chosen for data collection. Deductive Summative Analysis approach is used in the study. Areas such as workforce composition, inclusive compensation and benefits, millennials' induction to employment, and awareness creation still need more attention. The study was done based on available key terms from the sourced documents.

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1 Introduction

India is the largest democratic country, and its constitutional provisions (Legislative Department, 2025) and regulatory mechanisms are also strong and highly influential at the political and social levels of Indians. Though India has varied cultures, (Social Samosa. 2025), language, and belief systems, the common man's life is protected with the strong support of its constitutional provisions. Some of them are, the right to equality (Article 14), prohibition of discrimination (Article 15), equality of opportunity (Article 16), the right to life and personal liberty (Article 21), the right of minorities and promotion of educational and economic interests (Article 46), ensure that the treatment of its citizens in various walks of life are safe and sound. Thus, the constitutional provisions create a legal foundation in sectors, such as education, employment, and social welfare, promoting an inclusive society that respects diversity.

Though there is no specific legal mandate, various legal provisions and regulations indirectly promote Diversity, Equity, and Inclusion (DEI) principles in the workplace. They are, labor laws, corporate governance norms, and industry-specific regulations that create an inclusive and equitable work environment through anti-discrimination practices, gender parity, accommodations for disabilities, and prevention of sexual harassment. The Securities and Exchange Board of India (SEBI) has a Corporate Governance Code that encourages diversity on boards of publicly listed companies, focusing on gender diversity. But it is not a mandatory DEI policy. While there is no specific law mandating DEI frameworks, several national and international organizations have voluntarily embraced DEI guidelines. Codes by the Confederation of Indian Industry (CII), National Foundation for Corporate Governance (NFCG), and initiatives such as Environmental, Social, and Governance (ESG) frameworks, the United Nations Sustainable Development Goals (SDGs) focus mainly on promoting social justice, equality, and the rights of disadvantaged groups in trade and business.

2 Background

Internationally, companies have made DEI metrics a Key Performance Indicator (KPI) and have linked executive compensation to their direct contributions (HR Brew, 2025; Conference Board, The. 2025; HR Executive. (2025). With the advent

of the recent changes due to the anti-DEI executive orders (Whitehouse, 2025) and increasing legal and political challenges facing such initiatives of the United States of America (USA), the Diversity, Equity, and Inclusion (DEI) programs all across the globe are disrupted. A number of major corporations (Forbes, 2025; Ng, E., Fitzsimmons, et al., 2025) has rolled back their DEI programs. They are MLB, Warner Bros. Discovery, Goldman Sachs, Paramount, Bank of America, BlackRock, Citigroup, JPMorgan Chase, Morgan Stanley, Wells Fargo, Coca-Cola, PepsiCo, Disney, Deloitte, Google, NPR, Accenture, Amazon, Amtrak, the Smithsonian Institution, and the FBI. This move impacts the existing diversity targets, renaming programs, omitting DEI language from public reports, and discontinuing DEI partnerships across the globe (finance.yahoo.com, 2025).

To understand the reasons and effects of such moves, it is necessary to understand the lay theory of diversity that encompasses the zero-sum and win-win approaches. The zero-sum beliefs (ZSBs) presume that the efforts to advance diversity come at the expense of the majority; the win-win beliefs (WWBs) assume that diversity initiatives can benefit all racial groups. Proving the theory, the present administration of the United States of America (USA) is also of the opinion that the investments made in DEI initiatives are not giving any value to the money spent; at the same time, merit cannot be compromised for any radical ideologies.

Due to an executive order released in one corner of the world impacting the entire globe (HR Brew. In 2025, it is a must to understand the scenario concerning voluntary investments made by Indian organizations in Diversity, Equity, and Inclusion (DEI) programs. According to Aon India's 2022 National Wellbeing Survey India by Brand Equity Foundation (2023), 81% of Indian enterprises have indicated that their investment in employee wellbeing initiatives (including DEI initiatives) has increased since 2021.

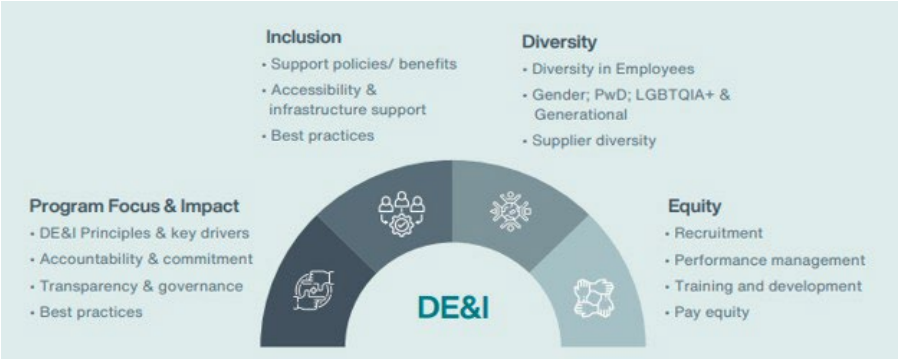

Figure 1: Diversity, Equity, and Inclusion Coverage
Source: India Brand Equity Foundation (2023)

Figure 1 above depicts the coverage of most DEI investments made by Indian organizations.

3 Review of literature

The term DEI includes the mere idea of tolerance and respect for others regardless of their age, gender, race, political and religious beliefs, assumed purposes and values, physical and mental abilities, and sexual orientation, (Burleson, et al., 2022; Park, C.H., Park, S. and Kwon, B., 2025). Investment in DEI initiatives has been looked at with various emotions and perspectives. From the point of view of an investor, it carries both positive and negative ideologies. Carla, F. et al's (2023) positive note on the partnership between Apple and CNote has been seen as a competitive advantage to both in terms of their investment in economic equality, racial justice, gender equity, and climate change initiatives. Through the lens of lay theories, the benefit or outcome of DEI investments would always be with win-win expectations, as noted by MIT Strategy Forum (2022). Corporate attention to DEI leads to long-term shareholder value, rather than short-term. It is a strong case for startup investors to integrate DEI into investment decisions (Kacperczyk, A. 2008; Standley, K., & Javorka, M., 2025). According to Mercer (2025), a investment consulting organization, those organizations exhibiting a strong DEI history, perform better, and their work environment boosts innovation (Amazing Workplaces, 2024; Armstrong, A., 2024). Though there are studies in DEI programs, policies, and initiatives in various sectors and policy levels, there is very little done on investments made in DEI. Hence, this study tries to provide wider knowledge

regarding the DEI perspectives and relevant investment policy decisions (Tucker, E., 2023). Management, communication, and business disciplines have incorporated some DEI vocabulary (Sethi and Cambrelen, 2022). Diversity has been studied about corporate leadership and gender equality (Nishii et al., 2018; Nishii and Leroy, 2020), particularly in the public relations profession (Meng and Neill, 2021; Shah, 2015; Topic, 2022); its effectiveness concerning corporate outcomes (Gonzalez and DeNisi, 2009) and globalization, workforce and inclusion (Shore et al., 2018), among several other related topics.

4 Research methods

Nifty 50, an Indian stock market Index representing the performance of the top 50 Indian companies listed as of 17th March 2025, in the National Stock Exchange (NSE), is the sample framework from which the sample of organizations was chosen for data collection. Documents such as (Integrated) Annual Reports (AR), Sustainability Reports (SR), Business Responsibility and Sustainability Reports (BRSR), ESG Reports, and Environmental Reports (some organizations have given DEI initiatives in their environmental reports) were retrieved from the respective home pages of the chosen organizations for identifying DEI words and texts used as shown in Figure 1. The period of the study is restricted to 2019 – 2024 (5) financial years. The final selection of documents went through a rigorous process in multiple stages, and ultimately, 40 organizations were chosen for the study, applying exclusion and inclusion strategies using the PRISMA (2024) protocol as follows:

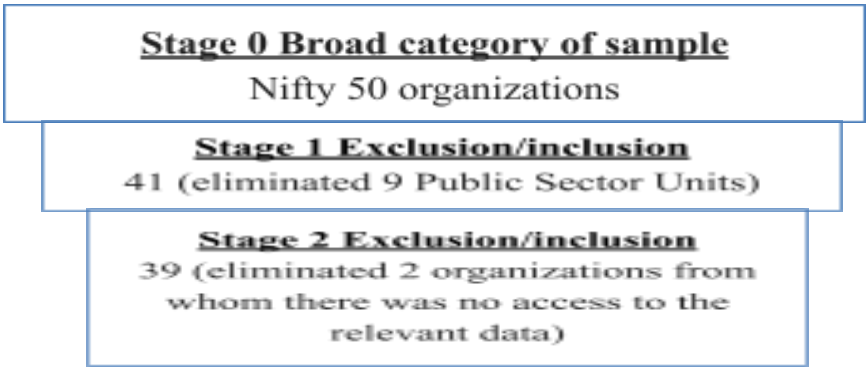

Figure 2: PRISMA Protocol (Sample Selection)

Out of the Nifty 50 organizations, nine public sector units (PSUs) were eliminated, as they have certain mandatory clauses to fulfill in terms of quota and other regulations (Tanya Settles, 2025), they do not fall under the volunteer investor, the purpose of the study, and two organizations from whom there was no access to the required data, also were eliminated.

Table 1: PRISMA Protocol (Year-wise Document Selection)

Year	(Integrated) Annual Reports	Sustainability Reports	Business Responsibility and Sustainability Reports	Environmental, Social, and Governance Reports	Total
2019-20	19	12	1	6	39
2020-21	17	13	3	7	40
2021-22	16	12	4	4	36
2022-23	16	13	1	6	36
2023-2024	11	9	4	10	34

Table 1 shows the year-wise selection of documents. As not all organizations have published or made their reports publicly available, or some reports do not have enough information or only one-line explanations are available, the selection of documents was extended to all available reports. Thus, Annual Reports (including integrated (AR), Sustainability Reports (SR), Business Responsibility and Sustainability Reports (BRSR), Environmental, Social and Governance Reports (ESGR) were included in the list.

Codes and categories

The codes and categories identified are the texts and words in the source documents. The entire collection of words and texts were classified into major codes and categories of various dimensions (the India Brand Equity Foundation, 2023) as follows:

The data were categorised into three major codes such as diversity, equity, and inclusion. Each major code was categorised as generic and specific.

Diversity-generic, diversity-company specific,diversity-policy specific, diversity-by-women-composition, diversity-by-LGBTQIIA+,

disability-specific, youth/millennials-specific were brought under the code 'diversity'. Equal benefits and open commitment to gender parity are considered under the code 'equity'. Explicitly stated as an equal opportunity employer, racial and ethnic inclusion, flexible work arrangements, and employee-as-a-parent support programs are brought under the code 'inclusion'.

The reported vocabulary that may not come under any of the above is brought under the 'not specific or combined, or not fitting' type.

Exclusion criteria

The words and/or texts or meaning to, "stakeholder inclusion, social, community, society, social welfare, community welfare, family, mandatory, corporate social responsibility terms, public sector, quota for minorities, mandate, regular technical learning and training as a part of continuous improvement, aspirant training, common management development programs, regular or common human rights training, regular health checkups, common grievance redressal mechanisms, common mentoring, mandatory board diversity, regular employee engagement and employee induction events, common or regular vacation and leave on medical grounds, legally mandated transfer and transport policies" were excluded. As the study is restricted to inbound investments of the employers, the social or outbound investments are excluded.

Inclusion criteria

The words and/or texts were grouped and taken as major, minor, and sub-dimension for discussion. Major dimensions were diversity, equity, and inclusion initiatives. Minor dimensions were grouped as specific to the company, culture, function, gender, ability, age, race, benefits, employment conditions, policy-related, global, or otherwise membership in DEI matters, support services, and special training offered and recognized with honors and awards for their success in in the DEI space. Specific dimensions were the specific initiatives stated as a unique feature of the organizations offered in the DEI space.

Analysis/Results

Deductive Summative Analysis approach is used in the study (Hsieh & Shannon, 2005). Based on the contents collated from the available reports, the frequency of each specific dimension has been connected to the respective specific dimension under the respective major dimension. The terms were carefully noted only once in the organization chosen, not as many as they appear. Thus, the observations were presented as follows:

Table 2: Dimension-based observations on DEI Initiatives

Major dimension	Specific Dimensions	Minor Dimensions	Frequency of occurrence by companies (names are not revealed) N=39	Percentage
Diversity-generic	**Company-specific diversity initiatives are given explicitly**		3	8
	Board Diversity Policy (only if women and/or DEI-specific terms are stated explicitly)		5	13
	Cultural diversity details are clearly stated		2	5
	The diversity hiring agenda is explicitly stated		19	49
	Gender Diversity-generic	Gender diversity targets	1	3
		Career support initiatives other than regular career plan events	7	18
		Diversity metrics, surveys, audits, reviews, and reporting information are explicitly stated	4	10
	Diversity by women	Diversity women network	1	3
		All women's branches/units established data explicitly stated	7	18

Major dimension	Specific Dimensions	Minor Dimensions	Frequency of occurrence by companies (names are not revealed) N=39	Percentage
		One or more gender specific initiatives exclusively for women	1	3
		Return-to-work policy for women in case of career breaks	9	23
		Women leadership-friendly initiatives	8	8
		Women-specific support, reward, and recognition programs organized (For e.g. Women-of-the-organizati on recognition)	9	23
		Women-in-every-team initiative stated	1	3
		The workforce composition by women is explicitly stated >=50% 31 to 49% 11 to 30% 1 to 10%	12 1 4 2 5	31
		The rate of women in leadership 1 to 10% 11 to 20% 21 to 30%	6 2 2 2	15
		Women in heavy-duty operations of the business	2	5
	LGBTQIIA+	LGBTQIIA+ friendly policies explicitly stated	10	26
		Gender-neutral utilities available	1	3
		LGBTQUI+ friendly environment ensured	2	5
		Gender reassignment benefits are given (Reimbursement of surgery expenses and	2	5

Major dimension	Specific Dimensions	Minor Dimensions	Frequency of occurrence by companies (names are not revealed) N=39	Percentage
		further medical support)		
		Transgender in heavy-duty operations	1	3
		LGBTQAI+ Specific recruitment program organized	1	3
	Disability	Disability-friendly policy	5	13
		Disability friendly accessibility in the workspace	10	26
		Support group exclusively for disabled	1	3
	Youth/Millennials	Workforce Composition by Millennials	2	5
Equity	**Equal benefits provided (beyond mandates only)**	Equal medical benefits to all	1	3
		Future commitments on gender parity are explicitly stated	10	26
Inclusion	**Explicitly stated as an equal opportunity employer**		11	28
	Racial and ethnic inclusion is explicitly stated		2	5
	Flexible work arrangements are provided as the need arises		16	41
	Employee as a parent (support programs offered)		12	31
Not specific or combined of all or not fitting into any of the above	**The DEI Policy is explicitly stated**		39	100

Major dimension	Specific Dimensions	Minor Dimensions	Frequency of occurrence by companies (names are not revealed) N=39	Percentage
	The Inclusion and Diversity Council is present		3	8
	DEI support group/resource group available		10	26
	DEI-specific training, empowerment, sensitization, and awareness programs offered		11	28
	Membership/partnership/deals with global DEI regulators/collectives		5	13
	Gained significant honors/awards for leadership in the DEI space		9	23

With the inclusion and exclusion criteria in mind, the documents have been carefully read, and the approaches adopted by the chosen organizations regarding their investment in DEI initiatives have been summarized and shown in Table 2.

5 Discussion

Experts believe that the organizations prone to DEI investments, make better decisions on scarce resources (ESG Dive, 2024; Tanya Settles, 2025; Standley, K., & Javorka, M., 2025). Though most of the employers across the globe feel and prove that the DEI initiatives help (Social Samosa. 2025) them achieve the innovation targets, culture-bound business goals and bring in varied perspectives to the business, many of them are rolling back on their planned programs and initiatives in response to the recent executive orders that were released by the present government of the USA (Morningstar, 2025). Both of these statements are proven to be contradictory to each other in practice, in this study. From the given observations, it is clear that certain specific areas boost the retention level (Armstrong, A., 2024; Avery et al. 2008) such as diversity hiring (Tanya Settles,

2025), return-to-work program, women recognition in leadership, (Tucker, E., 2023), LGBTQIIA+ policies, disability friendly policies (Avery, D.R., et al. 2013), efforts are seriously taken into account, but in certain areas such as workforce composition, inclusive compensation and benefits, millennials induction to employment and awareness creation (Tucker, E., 2023) still need more attention.

6 Conclusion

Based on the Deductive Summative Analysis of publicly available reports from 39 select Indian organizations listed on the Nifty 50 index, this study provides the prevalence and focus areas of corporate DEI initiatives in India between 2019 and 2024. The study indicates that there is a significant adoption of DEI policies across the studied organisations. The study focused on various aspects in which the corporations invest in DEI initiatives in India. All of them explicitly state a DEI policy. There is a notable emphasis on certain dimensions, particularly diversity hiring. Nearly half of them explicitly stated a diversity hiring agenda. Women-friendly initiatives such as return-to-work policies, women-specific support and recognition programs, and workforce composition by women also show considerable prevalence.

The adoption of flexible work arrangements and employee-as-a-parent support programs suggest a broader approach towards inclusive workplace practices. Specific gender diversity targets, detailed information on diversity metrics and reporting, initiatives for LGBTQIIA+ and disabled individuals beyond general policies and accessibility, and explicit focus on workforce composition by millennials are areas of less focus, with less explicit and frequent reporting.

In conclusion, while the studied Indian organizations demonstrate a strong foundational commitment to DEI through policy adoption and significant focus on diversity hiring and certain gender-related initiative. There is variability in the depth and breadth of reported initiatives across different dimensions of diversity, equity, and inclusion. This suggests that while progress is being made, a more comprehensive and explicitly communicated approach across all key DEI dimensions could further enhance inclusivity within these leading Indian corporations. The reliance on publicly available data necessitates caution in generalizing these findings, as the actual implementation and impact of these

initiatives may extend beyond what is publicly reported. Whether the DEI initiatives are adopted with a win-win approach or a zero-sum approach, there is a dire need to focus on aspects such as workforce composition, inclusivity in benefits, and, above all, greater awareness to be created among the stakeholders, especially among the employees.

Limitations

The study delved into understanding the corporate approach towards DEI investments on a conceptual level only. Hence, there is a scope for more depth of research into the impact of the investments on businesses. It was done based on the available key terms from the sourced documents. Hence, the terms that were not used by the chosen organizations are not covered in the study.

Originality/Value

The article is a work on various approaches adopted by Indian corporations in investing in DEI initiatives. It is an original work written based on secondary data sourced from the homepages of the respective organizations. This account will be a crucial resource for future researchers studying this period and its impact. International policy and its impact are the core idea of this work. Hence, this work provides valuable insights for both scholars and human resource experts working to advance DEI initiatives in their respective organizations.

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The Strategic Role of AI in Business Process Transformation and ESG Commitment

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This paper explores the impact of Artificial Intelligence (AI) on business process optimization, emphasizing its role in fostering sustainable management aligned with ESG (Environmental, Social, and Governance) principles. The study adopts a mixed-methods approach, combining quantitative survey data (n = 152) with qualitative insights from semi-structured interviews with professionals from diverse industries. The results reveal that AI implementation enhances operational efficiency, supports informed decision-making, and contributes to productivity gains. Key benefits include cost reduction, improved customer experience, and reallocation of human tasks to more strategic activities. Despite initial resistance from employees, proper training and change management proved crucial in ensuring successful adoption. The study also highlights challenges such as high implementation costs and ethical concerns. Findings suggest that AI can support long-term sustainable practices by enabling real-time data analysis, process automation, and predictive capabilities. Limitations include the geographical scope constrained to Portugal and the relatively small interview sample. This research provides valuable implications for managers aiming to integrate AI into existing systems to enhance competitiveness while supporting sustainability goals. It adds to the growing body of literature on the intersection of AI, ESG, and sustainable business strategy.

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1 Introduction

Artificial Intelligence (AI) is changing how organizations operate, offering tools to improve efficiency, reduce costs, and support faster, data-driven decisions. In a highly competitive and sustainability-focused environment, AI emerges not only as a technological solution but also as a strategic ally for aligning business performance with Environmental, Social, and Governance (ESG) goals (Wamba-Taguimdje et al., 2020; Alavi et al., 2024).

Recent studies show that AI can enhance ESG-related practices by improving resource efficiency, monitoring supply chains, and enabling transparency and personalization (Leszkiewicz et al., 2022). Firms adopting AI report better performance and agility (Ruiz-Real et al., 2021). However, most existing literature focuses on technical or ethical dimensions (Sadiku et al., 2020), with limited empirical evidence on how AI is integrated into business processes to support sustainable management. The human impact of AI—on roles, culture, and internal processes—also remains underexplored (Godkänt et al., n.d.).

This paper addresses that gap by examining how AI contributes to optimizing business processes while supporting ESG-aligned strategies. Using a mixed-methods approach, it analyses how AI impacts productivity and identifies which business areas benefit the most from its implementation.

Drawing on data from Portuguese companies, this paper provides practical insights into the dual role of AI as both an efficiency tool and a driver of sustainable transformation.

The remainder of this paper is structured as follows: Section 2 details the methodology; Section 3 presents and discusses the results; and Section 4 concludes with key implications and future research directions.

2 Theoretical Background / Literature Review

The integration of AI into business processes has been the focus of increasing scholarly attention due to its capacity to transform organizational performance and strategic decision-making. AI refers to computational systems capable of performing

tasks that typically require human intelligence, such as pattern recognition, learning, and decision-making (Pina Campos et al., 2022).

Business process optimization, on the other hand, is defined as the continuous improvement of organizational efficiency and effectiveness through automation and data analytics (Leszkiewicz et al., 2022). The convergence of these two areas suggests that AI can significantly enhance process automation, reduce operational costs, improve quality, and increase decision speed and accuracy (Wamba-Taguimdje et al., 2020).

Several studies have emphasized AI's ability to detect inefficiencies, automate repetitive tasks, and provide strategic recommendations through data-driven insights (Bharadiya et al., 2023; Mihai & Pica, n.d.). From customer experience to inventory management and fraud detection, AI applications are becoming increasingly embedded in organizational operations (Sadiku et al., 2020).

However, these advancements are not without challenges. High implementation costs, employee resistance, lack of specialized professionals, and data privacy concerns remain barriers to widespread AI adoption (Godkänt et al., n.d.; Oliveira, 2024). Ethical issues and regulatory requirements are particularly relevant when AI applications involve personal data or affect customer interactions (Soni et al., n.d.).

The literature emphasizes the importance of aligning AI strategies with ESG principles to ensure ethical and transparent deployment in business transformation (Ruiz-Real et al., 2021; Paula Da Silva et al., n.d.). Recent research by Wei and Zeng (2025) highlights how AI and big data analytics enhance ESG compliance by bridging disclosure gaps and improving risk assessment. Leveraging real-time data, AI supports more transparent and sustainable decision-making.

This study provides evidence of how firms adopt AI, manage related challenges, and perceive its effects on efficiency and sustainability.

3 Methodology

This study applies a mixed-methods approach to explore the role of AI in business process optimization and its contribution to sustainable management. Two research questions guide the analysis: (Q1) How does AI affect productivity in business processes?

(Q2) Which business processes benefit most from AI? A quantitative survey collected 152 valid responses from professionals working in organizations that have adopted or plan to adopt AI. Most respondents were aged 18–35 and held higher education degrees. The questionnaire focused on perceived AI impact on efficiency, decision-making, and strategic value. Data were analysed using SPSS (v.29).

To deepen understanding, five semi-structured interviews were conducted with professionals from diverse sectors. These interviews examined real-life AI applications, focusing on performance improvements, process changes, and employee adaptation. Qualitative data were analysed through content analysis using NVivo software.

4 Results

Quantitative analysis

From the 209 collected responses, 152 were retained for analysis. Respondents were active professionals in organizations that have already implemented or plan to implement AI, ensuring data relevance to the study's objectives. The majority were aged 18–35 (64.5%) and held higher education degrees (83%). Most were employed (80.3%) and represented diverse sectors including IT, manufacturing, finance, health, and tourism. Company sizes ranged from microenterprises (13.2%) to large firms (24.3%), with a balanced distribution across SMEs.

Table 1 summarizes the perceived impact of AI. Participants reported high satisfaction (M = 4.08), effectiveness (M = 4.01), and positive expectations for future impact (M = 4.15). AI was seen as instrumental in improving decision-making (M = 3.98), process transformation (M = 4.00), and personalization (M = 4.09). These results confirm that AI is valued not just for efficiency, but also for strategic and customer-related functions.

Table 1: AI Implementation Impact, descriptive statistics

Item	Question	Mean (M)	Std. Dev. (DP)
IMPCT1	Impact of AI implementation on decision-making	3.98	1.02
IMPCT2	Satisfaction with current AI solutions	4.08	0.90
IMPCT3	Effectiveness of implemented AI solutions	4.01	0.91
IMPCT4	Impact of AI implementation on business process transformation	4.00	0.86
IMPCT5	Effectiveness of strategies for overcoming AI implementation barriers	4.00	0.90
IMPCT6	Expectations regarding AI's future impact on process optimization (next 5 years)	4.15	0.86
PERS	Importance of personalization in customer experience	4.09	1.06

Source: own elaboration. Scale Notes: IMPCT1: Scale from 1 (No impact) to 5 (High impact); IMPCT2: Scale from 1 (Very dissatisfied) to 5 (Very satisfied); IMPCT3 & IMPCT5: Scale from 1 (Not effective) to 5 (Very effective); IMPCT4: Scale from 1 (No impact) to 5 (Significant impact); IMPCT6: Scale from 1 (Very low expectations) to 5 (Very high expectations); PERS: Scale from 1 (No importance) to 5 (High importance)

Qualitative Analysis

To complement the quantitative findings, a qualitative study was conducted through semi-structured interviews with five professionals from various sectors and company sizes in Portugal. This approach aimed to answer two core research questions: (Q1) How is productivity in a company affected by the use of AI in business processes? and (Q2) Which business processes are most benefited by AI implementation?

Three major thematic categories emerged from the content analysis:

1. Operational Efficiency: respondents consistently emphasized measurable improvements in key performance indicators. For example, Interviewee 1 (logistics sector) stated, "AI-based route optimization reduced our fuel costs and delivery times significantly." Another interviewee (Interviewee 3) noted,

"Our demand forecasting accuracy increased by 30% after implementing predictive algorithms."

2. Workforce Transformation: participants described how AI shifted the focus of employee tasks from routine operations to more strategic functions. Interviewee 1 mentioned, "Manual and repetitive work was drastically reduced, freeing up our staff for more analytical roles." Interviewee 4 reflected, "Although there was initial resistance, training sessions helped staff see how AI tools made their jobs more impactful and less monotonous."
3. Strategic Innovation: several interviewees reported that AI adoption encouraged a broader cultural shift within their organizations. Interviewee 2 highlighted, "Beyond efficiency gains, AI fostered a spirit of innovation in our company—we are now more open to exploring new technologies and more resilient in the face of change."

The processes most frequently cited as benefitting from AI implementation included inventory management, route optimization, demand forecasting, and customer service—particularly through the use of chatbots and virtual assistants.

5 Discussion

This study shows that AI contributes significantly to business process optimization and supports sustainable management aligned with ESG goals. The mixed-methods approach provided complementary insights into both perceived benefits and practical applications.

Survey results indicate high levels of satisfaction and effectiveness regarding AI's role in decision-making, process transformation, and strategic planning, with average scores above 4.00. These findings suggest that AI is seen not only as a tool for efficiency but also for long-term value creation, confirming previous research (Wamba-Taguimdje et al., 2020).

Interviews reinforced these results with concrete examples of improved logistics, demand forecasting, and operational cost reduction. Respondents described how AI allowed the automation of routine tasks, freeing staff to focus on higher-value

activities. This aligns with literature highlighting the human capital potential of AI (Godkänt et al., n.d.; Mihai & Pica, n.d.).

Resistance to adoption was initially present, but diminished with training and clear communication, confirming the importance of inclusive implementation strategies (Pina Campos et al., 2022). Moreover, participants described a cultural shift towards innovation, echoing findings by Bubphapant & Brandão (2024), where AI adoption fosters openness to experimentation and strategic renewal.

Overall, the results highlight AI's dual contribution: improving operational performance and enabling sustainable, future-ready business models.

6 Conclusions

This study explored how AI supports business process optimization and sustainable management. Using a mixed-methods approach, it combined survey data and interviews with professionals from Portuguese companies.

The results confirm that AI improves productivity through automation, predictive insights, and enhanced decision-making. It enables resource optimization and contributes to long-term value creation, supporting the first research question (Q1). Furthermore, processes such as logistics, forecasting, and customer service emerged as the most positively impacted, answering (Q2).

The findings also show that AI transforms workforce roles by reducing repetitive tasks and promoting strategic engagement. While initial resistance was reported, effective training and leadership helped overcome these challenges. A secondary benefit identified was a cultural shift toward innovation and ESG awareness.

This research contributes original empirical evidence on AI's role in driving both operational and sustainable performance. Its value lies in bridging the gap between AI application and ESG-aligned management in real business contexts.

Limitations include the geographic scope (Portugal) and a relatively small qualitative sample. Future research could explore long-term effects of AI adoption, cross-sector differences, and the integration of AI in ESG measurement and reporting frameworks.

In short, AI is not only improving how companies operate—it is shaping how they prepare for a more sustainable and competitive future.

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From Routine to Intuition: AI's Role in Organization's Governance and Management Decision-Making

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Nowadays, the increasing use of AI in corporate governance and management as well as business decision-making at various levels presents both opportunities and challenges. This paper integrates corporate governance and management structure, decision-making processes, and the EU AI regulatory framework. It examines how AI enters into decision-making processes in business contexts while taking into consideration ethical and legal standards. The research is based on the MER model of integral corporate governance and management, different decision-making approaches (intuitive, analytical, routine), and the AI-related EU regulatory framework (the EU AI Act). By integrating the above, this study provides a framework for responsible AI adoption in sustainable governance and management. The findings contribute to discussions on ethical use of AI in business in line with the ESG challenges in the age of AI.

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1 Introduction

This paper aims to describe an organization's governance and management from the selected process dimension of the MER model of integral management (Belak, 2010; Duh, 2024; Duh & Štrukelj, 2011; 2023) in correlation with routine, analytical and intuitive decision-making possibilities (Agor, 1989; Koziol-Nadolna & Beyer, 2021; Sinnaiah et al., 2023; Smith et al., 2009; Vinod, 2021) and the related use of AI. Because business decisions can nowadays be made with the use of AI, the EU AI regulatory framework will be discussed. The main focus of the paper is to show the interdependence between the organization's governance, management, decision-making and AI use-related issues. The research question reads: How can the interdependence between the process of governance and management, decision-making and AI be demonstrated?

Research objectives are thus based on the discussion on how AI influences ethical decision-making in organizations' governance and management, some challenges that arise when using AI in decision-making governance and management processes and how the EU AI Act guides ethical AI adoption.

Our study is qualitative, and it draws upon AI's role in governance and management, discussed within the framework of the MER model of integral management (Belak, 2010; Duh, 2024; Duh & Štrukelj, 2011; 2023). We used this model as the basis for this paper and upgraded it with our own vision of the possibilities of using AI (e.g., Csaszar et al., 2024; Keppeler et al., 2025; Szukits & Móricz, 2024) in its process dimension according to the Dialectical Systems Theory (Mulej, 1974 and later; Mulej et al., 2013). Decision-making literature was analysed. We examined how AI should be integrated with intuitive, analytical, and routine decision models (Agor, 1989; Csaszar et al., 2024; Keppeler et al., 2025; Szukits & Móricz, 2024).

The research positions AI as a moderating factor between governance and management structures and business decision-making. Relationships between AI-driven decision-making and ethical business practices are presented.

2 Conceptual Framework: AI and Decision-Making in Business

2.1 AI and Corporate Governance and Management in the MER Model of Integral Management and in Ethical Decision-Making

The MER model of integral management takes into account the organization itself, its working environment (i.e. industry and wider), and the intangible factors that contribute to the greater success of the organization (Belak, 2010; Duh, 2024; Duh & Štrukelj, 2023). The model contains key selected content classified into three sections: (1) Governance and management (as a process, institution and instrumental system), (2) The organization itself and the environment, and (3) Factors of company success. This paper focuses only on the process dimension of governance and management.

Decision-making takes place at different levels. The highest level is the level of business policy, where owners as governors decide on the vision and business policy. At this level, AI can be used as a generator of (innovative) ideas and as a proposer of different variants of the organization's vision and its business policy. Business policy is implemented at a lower level, i.e. the level of strategic management, at which top managers search for strategic development options and possible strategies, economically evaluate possible strategies and select the most appropriate ones, and then program their development, which defines the optimal way of their implementation. At this level, AI can be used for ideas for searching for development options or for computational operations of economic evaluation and selection of possible strategies. The lowest level in the organizational structure is the executive management level, which is divided into tactical and operational levels. From a process perspective, at the tactical level of executive management, middle managers provide the organization with the necessary resources and optimally allocate them (by departments, projects, etc.). At the lowest decision-making level, the operational level of executive management, lower managers operationally allocate executive tasks to workers in the basic (executive) process. AI can also be used for routine work at the executive management level to a limited extent to make suggestions for improving the organization's business processes.

Decision-making is a task that ensures the development and operations of every organization. At all levels of governance and management processes, it is necessary to perform all basic management functions, which include planning, organizing, direct leadership / management and control. Within each of these basic management functions, all process management functions are performed. These are preparatory information activities (where the ethical use of AI can be of great help), decision-making and action (we do not recommend the use of AI for the latter two). This shows the evolution of AI from a supporting tool to an active decision-making agent and implicates the importance of ethical decision-making in corporate governance and management. When determining the relevance of AI applications in decision-making, we subjectively used our own expertise and experience (e.g., Csaszar et al., 2024; Keppeler et al., 2025; Szukits & Móricz, 2024) in accordance with the insights of the Dialectical Systems Theory (Mulej, 1974 and later; Mulej et al., 2013).

There are three types of ethical decision-making in business, i.e. intuitive analytical, and routine (e.g., Agor, 1989; Csaszar et al., 2024; Kozioł-Nadolna & Beyer, 2021; Sinnaiah et al., 2023; Smith et al., 2009; Szukits & Móricz, 2024; Vinod, 2021). See Table 1 for their descriptions and the examples of the related AI-use.

Table 1: Three types of decision-making

Type	Description	Example
Intuitive decision-making	It is fast and is based on experience, instincts, and tacit knowledge. AI's role is in enhancing human intuition through pattern recognition and predictive analytics.	AI-assisted hiring decisions based on candidate data trends.
Analytical decision-making	It is data-driven, structured, systematic, and logic-based decision-making. AI's role is in processing large data sets for informed decisions	AI-driven risk analysis in financial investments.
Routine decision-making	It consists of repetitive, rule-based, automated decisions that follow standard procedures. AI's role is in automating routine tasks to improve efficiency.	AI-driven customer service chatbots handling common inquiries.

2.2 The EU AI Regulatory Framework

The increasing application of AI in business and broader has resulted in the need for regulatory frameworks addressing various aspects of AI utilization in organization processes. This section of the paper gives a brief overview of the first legal framework on AI (globally), i.e. the EU Regulation 2024/1689 (i.e. the EU AI Act) (Regulation 2024/1689).

As the binding legislative act of the European Union (the EU), the EU AI Act addresses the role of AI in decision-making primarily in the context of risk assessment and regulation. Overall, it outlines a governance framework for AI. Concerning the ethical principles of AI use, the EU AI Act incorporates the following principles: human agency and human oversight, protection of privacy and data governance, transparency, diversity, non-discrimination and fairness, societal and environmental wellbeing, and accountability (Regulation 2024/1689, Article 27). The EU AI Act stresses the need for a human-centric and trustworthy AI. Regarding the trustworthiness of AI, the EU AI Act stipulates its application in such a way that human health, safety and fundamental rights are not endangered. Moreover, trustworthy AI systems are to integrate mechanisms which allow for a significant human oversight and intervention to override any outputs (i.e. AI decisions) which may lead to harm. In other words, the EU AI Act stresses that AI should assist in and not replace human decision-making. In other words, human judgement should remain central, especially when it comes to decisions affecting the afore mentioned health, safety and fundamental rights (e.g. in high-risk decision-making).

With regard to risks associated with the use of AI and the related risk management, businesses ought to adopt governance structures which evaluate the risks associated with the deployments of AI systems. For example, high-risk AI applications in business, which can potentially significantly impact individuals' rights and safety, are seen in the context of employment and workforce management; such is the use of AI in recruitment or employment conditions (Regulation 2024/1689, Article 57). Next, organizations are to include various stakeholders (e.g. civil society) to ensure that a diversity of insights informs their operational decisions and business strategies (Regulation 2024/1689, Articles 111, 116). Focusing on employees, the regulation encourages organizations to promote AI literacy to facilitate their management

practices and to, consequently, make better-informed management decisions regarding the implementation of AI systems (Regulation 2024/1689, Article 20).

3 Results and Discussion

Business owners and managers are faced with a growing role that AI has in organization's governance, management and decision-making regardless of whether these are development issues (long, medium or short term) or resulting business operation issues (Csaszar et al., 2024; Keppeler et al., 2025; Sinnaiah et al., 2023). In AI-driven business decision-making, it is important to give thought to ethical considerations. AI should only be an aid in collecting data and not a tool that prepares final analyses or even makes decisions as a decision-maker.

When defining values, vision and business policy, the owners of organizations must proceed from their own interests and consider the interests of all stakeholders (Duh, 2024). We propose that these decision-making definitions are responsible and sustainable (Duh and Štrukelj, 2023).

When defining strategies, top managers must proceed from real development opportunities and market needs that the organization is able to satisfy in a (socially, environmentally, also towards owners) responsible and sustainable manner (Belak, 2010; Duh, 2024; adapted).

Middle and low-level managers must, in accordance with the owners' justifications and top management guidelines, appropriately provide and allocate resources and implement tasks. While low-level managers make the most routine decisions, top managers should make decisions analytically, with the help of various strategic tools, and owners usually consider their intuition in addition to information sources (Belak, 2010; Duh, 2024; adapted). When these decisions are made using AI, decision-makers must be aware that AI is just a tool and that they are the ones who must ensure not only the appropriateness but also the ethics of the decisions made.

Different decision-making styles have different characteristics and are used to different extend at different levels of governance and management process (based on Agor, 1989; Csaszar et al., 2024; Keppeler et al., 2025; Sinnaiah et al., 2023; Koziol-Nadolna & Beyer, 2021; Sinnaiah, 2023; Smith et al., 2009; Szukits & Móricz,

2024; Vinod, 2021 and authors' own knowledge). At the business policy level, decision-making is predominantly intuitive, and to a lesser extend also analytical. At the strategic management level, decision-making is mostly analytical; it can also be intuitive. At the tactical (executive) management level the decisions are mostly routine; but some decision-making is also analytical. At the lowest, i.e., operational management level, most decisions made are routine decisions.

This classification provides a sufficiently comprehensive overview of the three decision-making styles and their application at different levels of governance and management decision-making. Each style has unique characteristics, strengths, and ideal contexts of application. Understanding these differences can help individuals and organizations choose the most appropriate approach for specific situations at specific governance and management process at different levels of decision-making. The key is recognizing that these styles are not mutually exclusive. Effective decision-makers often blend these approaches, adapting their method to the specific context, complexity of the problem, and available resources. The use of AI in this context should comply with the guidelines given by the relevant regulatory framework.

4 Conclusions

This study adopted a conceptual research approach to integrate three key dimensions: (1) Organization governance and management levels of decision-making, where the role of AI is mostly important in shaping corporate leadership, accountability, and compliance; (2) Decision-making types, where the emphasis is on the interplay between intuitive, analytical, and routine decision-making processes; and (3) The EU Act, which stresses the ethical dimension of ethical adoption of AI in business.

The topic under study, which links governance and management processes at different levels of decision-making with decision-making types and the EU AI Act, is not only new, but also largely unexplored, at least in depth. We found out that there are many ethical and legal challenges, including recommendations for integrating AI with ethical decision-making. AI's role in business ethics and sustainability is still evolving and there are many potential conflicts between AI automation and ethical business practices. The researchers and business

professionals should therefore address AI bias and fairness concerns. It is important to ensure transparency and explainability in AI corporate adoption challenges and AI-driven decisions. Emerging AI technologies bring many development opportunities, including their implications for governance. Managing AI-human collaboration in governance and management roles is to be explored further, especially with reference to the resistance to AI integration in traditional decision-making structures. It is also necessary to consider cost and resource considerations for AI implementation. Furthermore, global future regulatory trends and business adaptation strategies concerning AI are to be explored and expanded. The development of AI auditing frameworks for corporate accountability is also needed.

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9TH FEB INTERNATIONAL SCIENTIFIC CONFERENCE: SUSTAINABLE MANAGEMENT IN THE AGE OF ESG AND AI: NAVIGATING CHALLENGES AND OPPORTUNITIES

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The Faculty of Economics and Business, University of Maribor, organized with the co-host Rajagiri Business School, Kerala, India, the 9th International Scientific Conference titled *Sustainable Management in the Age of ESG and AI: Navigating Challenges and Opportunities*. The international scientific conference brought together international researchers, professionals, and practitioners to discuss sustainable management in the context of the increasing importance of Environmental, Social, and Governance (ESG) factors and the rapid advancement of Artificial Intelligence (AI). Participants presented academic contributions addressing the challenges and opportunities arising from the integration of ESG principles and advanced technologies into strategic and managerial processes. The event served as a platform for interdisciplinary knowledge exchange and fostered collaboration between academia and the business sector with the aim of developing innovative and responsible management practices that support a sustainable future.

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