

CONTRIBUTION OF INDUSTRY 4.0 TO SUSTAINABLE DEVELOPMENT

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Abstract The main purpose of this paper is to discuss how implementation of Industry 4.0 principles in organizations contributes to sustainable development. Based on desk research of literature, several contributions of Industry 4.0 to sustainable development are outlined. We discussed the issue of monitoring of Industry 4.0 contributions to sustainable development in the context of existing models for assessing Industry 4.0 implementation level. The paper provides fertile ground for further examination in this field and development of relevant model for assessment Industry 4.0 implementation level, while also considering Industry 4.0 contribution to sustainable development.

Keywords:

Industry 4.0, sustainable development, maturity assessment models, SDG-17, models for assessment

JEL:

I21, I30, I60, M14

1 Introduction

The importance of social responsibility in organizations has grown significantly in recent years (Potocan & Nedelko, 2021). In the last period, there has been a lot of talk about sustainable development, which can be supported by implementing the principles of Industry 4.0 in organizations (Ching et al., 2022; Sierra-Henao et al., 2020).

The central purpose of sustainable development phenomena is to establish such a way of functioning of individuals and all entities in society, with special emphasis on organizations, which will enable a decent life for the generations that come after us (Elkington, 2004).

The principles of Industry 4.0 have been intensively implemented in organizations in the last decade, mainly with the aim of improving productivity, operations in general, reducing costs, automating operations, and gaining other advantages (Črešnar et al., 2022; Dabić et al., 2023). Naturally, there is a strong tendency towards research that would connect the concepts of sustainable development and Industry 4.0 (Sierra-Henao et al., 2020).

In this context, there are sporadic studies that mainly represent the expected contributions of Industry 4.0 to sustainable development (Ching et al., 2022; Mukhuty et al., 2022; Varela et al., 2019). But, despite the increased interest from researchers on examining the impact of Industry 4.0 on sustainable development (Ghobakhloo et al., 2021; Khan et al., 2021), relatively little is still known about how these benefits can be measured and monitored in practice.

We will emphasize several benefits how implementation of the Industry 4.0 principles in organizations can contribute to sustainable development. We will further discuss how we can measure the level of contribution of the implementation of the principles of Industry 4.0 to sustainable development, within the framework of known models for evaluating the level of implementation of Industry 4.0 in organizations. We will provide some starting points for further work and model development.

2 Literature Review

Digitalization has become an important part of the daily operations of organizations in the last decade. In the beginning, the researchers paid attention mainly to the development of the concept of Industry 4.0 (Zhou et al., 2015), which was followed by a large share of research that examined the effects of the implementation of the Industry 4.0 concept in the practice of the organizations. For example, through case studies (Otlés & Sakalli, 2019) and in connection with lean and six sigma concepts (Wagner et al., 2017; Yeen Gavin Lai et al., 2019).

Industry 4.0 for organizations brings productivity improvement, cost reduction, energy consumption reduction, etc. At the beginning, the implementation of the principles of Industry 4.0 was mainly in the manufacturing sector (Tortorella & Fettermann, 2018), but later the implementation also started in the service sector, as well in public administration (Ghobakhloo et al., 2021). The monitoring of changes in productivity due to the implementation of Industry 4.0 principles was often highlighted (Dabić et al., 2023; Fragapane et al., 2022; Tortorella & Fettermann, 2018).

Due to the emergence of new challenges related to the implementation of Industry 4.0 in organizations, researchers began to point out the importance and relevance of soft factors in the implementation of Industry 4.0 in the organization (Črešnar et al., 2022; Schneider, 2018). One such challenge is the contribution of Industry 4.0 to sustainable development.

Sustainable development is a key concept in the framework of ensuring the welfare of society and its members. Concern for sustainable development or the socially responsible operations of the organization is today strongly articulated in various documents, whereby it is the most exposed in recent times United Nations 2030 Agenda for Sustainable Development Goals (SDGs -17). This agenda allow us to judge how much the organization contributes to sustainable development (Mukhuty et al., 2022).

There are few sporadic attempts that outline the association between the implementation of Industry 4.0 and its effects and contribution to sustainable development (Ching et al., 2022; Ghobakhloo et al., 2021; Khan et al., 2021).

In order to make implementation easier and to know the state of the organization's digitalization level, many models for assessing the level of Industry 4.0 implementation have been developed. These models reveal to us the dimensions of digitalization of organizations through various aspects. For instance, commonly used are models developed by Fraunhofer institute and University of Warwick (Agca et al., 2017; Črešnar et al., 2022). We also know the model, where management tools are used in the assessment of Industry 4.0 implementation level (Črešnar et al., 2020).

Seen through the prism of assessing the level of Industry 4.0 implementation in organizations, the most frequently used models do not directly and to a lesser extent indirectly include items related to the sustainable development. For instance, we can find in those models increased productivity, lead times, real-time tracking, etc.

After reviewing the existing models for assessing the level of implementation of Industry 4.0, it soon becomes clear that the existing models do not contain or to a very small extent, items that would enable us comprehensive assessment of the contribution of Industry 4.0 to sustainable development, within the framework of assessments of the level of implementation of Industry 4.0 in organizations.

Therefore, in the following section, we will present a series of contributions of Industry 4.0 to sustainable development, which will represent items to complement the existing assessment models.

3 Industry 4.0 and its Contribution to Sustainable Development

Industry 4.0 can contribute to sustainable development in several ways:

1. Increased efficiency and productivity: Industry 4.0 technologies, such as Internet of Things (IoT), artificial intelligence (AI), and big data analytics, can enhance the efficiency and productivity of manufacturing processes, reducing the amount of energy and raw materials required to produce goods.
2. Reduced waste: Smart manufacturing processes enabled by Industry 4.0 technologies can reduce waste by optimizing material usage, minimizing rejected products, and decreasing the consumption of energy and water.

3. Improved traceability and transparency: Industry 4.0 technologies can enable greater traceability and transparency in supply chains, empowering consumers and stakeholders to make informed decisions about sustainable products and ethical sourcing.
4. Lower carbon footprint: Smart factories enabled by Industry 4.0 technologies can reduce their carbon footprint through the use of renewable energy sources, energy-efficient equipment, and reduced energy consumption.
5. Support for circular economy: Industry 4.0 technologies can support the shift towards a circular economy by enabling more efficient and effective resource management, recycling, and repurposing of materials.
6. Innovation in sustainable products: Industry 4.0 can foster innovation in sustainable products by providing new design and production capabilities enabled by digital technologies, such as additive manufacturing and virtual prototyping.
7. Sustainable supply chain management: Industry 4.0 technologies can enable better supply chain management, reducing transportation emissions, optimizing logistics and reducing waste along the supply chain.
8. Improved water management: Industry 4.0 technologies can help monitor and manage water consumption in factories and identify opportunities for reduction or reuse of water, contributing to sustainable water management.
9. Safety and health benefits: Industry 4.0 technologies can improve worker safety and health through the use of automated processes, wearable devices, and virtual training, reducing workplace accidents and injuries.
10. Social responsibility: Industry 4.0 technologies can enhance social responsibility by promoting ethical and sustainable practices in production, increasing transparency and accountability, and improving working conditions for employees.

4 Discussion and Conclusions

It can be concluded that there is an extremely large amount of literature on the topic of sustainable development, which has been intensively developed in the last two or three decades. But the connection between the implementation of Industry 4.0 and sustainable development is still weak. Even more, models for assessing the level of Industry 4.0 implementation do not include items that would enable a comprehensive assessment of Industry 4.0 implementation, while also taking into the consideration the sustainable development dimension. However, we can find a lot of indirect links where, based on the assessment of individual criteria regarding implementation of Industry 4.0, we can decide what the contribution could be or impact on sustainable operations. But this is not enough for a comprehensive evaluation of the contribution of Industry 4.0 to sustainable development.

The listed contributions of Industry 4.0 to sustainable development are thus a starting point for creating criteria for assessment (e.g. KPI) of the impact of Industry 4.0 on sustainable development. The existing models for assessing the level of implementation of Industry 4.0 principles would thus need to be complemented with the items measuring "sustainable development". This would give us a more comprehensive picture of the level of implementation of Industry 4.0, while also considering sustainable development goals of the society.

One of the most important directions of further research will be the development of a comprehensive model for assessing the level of implementation of Industry 4.0, which will also include items that will enable the assessment of the level of contribution of Industry 4.0 to the sustainable functioning of organizations.

The central limitation of this paper stems from a purely theoretical study of the contribution of Industry 4.0 to the achievement of sustainability goals.

References

- Agca, O., Gibson, J., Godsell, J., Ignatius, J., Davies, C. W., & Xu, O. (2017). *An industry 4 readiness assessment tool*. WMG-The University of Warwick.
- Ching, N. T., Ghobakhloo, M., Iranmanesh, M., Maroufkhani, P., & Asadi, S. (2022). Industry 4.0 applications for sustainable manufacturing: A systematic literature review and a roadmap to

- sustainable development. *Journal of Cleaner Production*, 334, Article 130133. <https://doi.org/10.1016/j.jclepro.2021.130133>
- Črešnar, R., Dabić, M., Stojičić, N., & Nedelko, Z. (2022). It takes two to tango: technological and non-technological factors of Industry 4.0 implementation in manufacturing firms. *Review of Managerial Science*. <https://doi.org/10.1007/s11846-022-00543-7>
- Črešnar, R., Potočan, V., & Nedelko, Z. (2020). Speeding up the implementation of industry 4.0 with management tools: Empirical investigations in manufacturing organizations *Sensors (Switzerland)*, 20(12), 1-25. <https://doi.org/10.3390/s20123469>
- Dabić, M., Maley, J. F., Črešnar, R., & Nedelko, Z. (2023). Unappreciated channel of manufacturing productivity under industry 4.0: Leadership values and capabilities. *Journal of Business Research*, 162, 113900. <https://doi.org/https://doi.org/10.1016/j.jbusres.2023.113900>
- Elkington, J. (2004). Enter the Triple Bottom Line. In A. Henriques & J. Richardson (Eds.), *The Triple Bottom Line: Does it all add up* (pp. 1-16). Earthscan.
- Fragapane, G., Ivanov, D., Peron, M., Sgarbossa, F., & Strandhagen, J. O. (2022). Increasing flexibility and productivity in Industry 4.0 production networks with autonomous mobile robots and smart intralogistics. *Annals of Operations Research*, 308(1), 125-143. <https://doi.org/10.1007/s10479-020-03526-7>
- Ghobakhloo, M., Iranmanesh, M., Grybauskas, A., Vilkas, M., & Petraitė, M. (2021). Industry 4.0, innovation, and sustainable development: A systematic review and a roadmap to sustainable innovation. *Business Strategy and the Environment*, 30(8), 4237-4257. <https://doi.org/10.1002/bse.2867>
- Khan, I. S., Ahmad, M. O., & Majava, J. (2021). Industry 4.0 and sustainable development: A systematic mapping of triple bottom line, Circular Economy and Sustainable Business Models perspectives. *Journal of Cleaner Production*, 297, 126655. <https://doi.org/10.1016/j.jclepro.2021.126655>
- Mukhty, S., Upadhyay, A., & Rothwell, H. (2022). Strategic sustainable development of Industry 4.0 through the lens of social responsibility: The role of human resource practices. *Business Strategy and the Environment*, 31(5), 2068-2081. <https://doi.org/10.1002/bse.3008>
- Otles, S., & Sakalli, A. (2019). Industry 4.0: The Smart Factory of the Future in Beverage Industry. In A. M. Grumezescu & A. M. Holban (Eds.), *Production and Management of Beverages* (pp. 439-469). Woodhead Publishing. <https://doi.org/https://doi.org/10.1016/B978-0-12-815260-7.00015-8>
- Potocan, V., & Nedelko, Z. (2021). The Behavior of Organization in Economic Crisis: Integration, Interpretation, and Research Development. *Journal of Business Ethics*, 174(4), 805-823. <https://doi.org/10.1007/s10551-021-04928-8>
- Schneider, P. (2018). Managerial challenges of Industry 4.0: an empirically backed research agenda for a nascent field. *Review of Managerial Science*, 12(3), 803-848. <https://doi.org/10.1007/s11846-018-0283-2>
- Sierra-Henao, A., Muñoz-Villamizar, A., Solano-Charris, E., & Santos, J. (2020). Sustainable development supported by industry 4.0: A bibliometric analysis. In *Studies in Computational Intelligence* (Vol. 853, pp. 366-376). https://doi.org/10.1007/978-3-030-27477-1_28
- Tortorella, G. L., & Fettermann, D. (2018). Implementation of industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research*, 56(8), 2975-2987. <https://doi.org/10.1080/00207543.2017.1391420>
- Varela, L., Araújo, A., Ávila, P., Castro, H., & Putnik, G. (2019). Evaluation of the relation between lean manufacturing, Industry 4.0, and sustainability. *Sustainability (Switzerland)*, 11(5), 1439. <https://doi.org/10.3390/su11051439>
- Wagner, T., Herrmann, C., & Thiede, S. (2017). Industry 4.0 Impacts on Lean Production Systems. *Procedia CIRP*, 63(Supplement C), 125-131. <https://doi.org/https://doi.org/10.1016/j.procir.2017.02.041>

- Yeen Gavin Lai, N., Hoong Wong, K., Halim, D., Lu, J., & Siang Kang, H. (2019). Industry 4.0 Enhanced Lean Manufacturing. Proceedings of 2019 8th International Conference on Industrial Technology and Management, ICITM 2019,
- Zhou, K., Taigang, L., & Zhou, L. (2015, 15-17 Aug. 2015). Industry 4.0: Towards future industrial opportunities and challenges. 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD).