Volume XXI, Issue (1) (2025) 649-659

International May Conference on Strategic Management

DOI: 10.5937/IMCSM25649K *Original Research*

DIGITAL READINESS LEVEL (DLR) AND TECHNOLOGY ORGANIZATION ENVIRONMENT (TOE) METHODOLOGY IMPLEMENTATION ON SME-S INDUSTRY 4.0 IMPLEMENTATION

Aleksandra Kovačević, Aleksandar Jankulović *

Belgrade Metropolitan University, Faculty of management, Serbia

Abstract: Implementation of Industry 4.0 to Small and Medium Enterprises (SMEs) induces various challenges. The investigation of these issues affecting SMEs is extremely rare, and thus this research has theoretical and especially practical implication on spreading Industry 4.0 implementation. The research is focused on implementation of the Digital Readiness Level (DRL) model and the Technology Organization Environment (TOE) framework for SMEs analyzing Industry 4.0 implementation and readiness. Research demonstrates the suitability of these two models and their shared dimensions. These elements and dimensions are applied to SMEs' digital readiness for Industry 4.0 and serve as suitable instruments for this kind of examination. According to research, there are a number of new influencing factors that are crucial for the implementation of Industry 4.0. These include the volatility of business process parameters, business specificity, user satisfaction, service quality, workforce presence, external knowledge inclusion, funding program research, and the visualization of future improvements. The study suggests aspects that are of main interest to be implemented for the successful implementation of Industry 4.0 based on analysed factors and outcomes.

Keywords: Industry 4.0, SMEs, digital readiness assessment, Digital Readiness Level (DLR), Technology-Organization-Environment (TOE)

1. INTRODUCTION

The fourth industrial revolution, known as Industry 4.0, includes technologies that present unprecedented challenges to all businesses, including SMEs (Mittal et al., 2018). The implementation of digitalization and industry 4.0 technology presents a number of challenges as well as the important organizational adjustments and work that are required. On the other hand, without their use the company, organizations and the country's economy as a whole, have no chance of survival and development. All of this implies increasing complexity and

* *Corresponding author: aleksandar.jankulovic@metropolitan.ac.rs*

Aleksandra Kovačević, ORCID: 0009-0001-2972-9968
Aleksandar Jankulović, ORCID: 0000-0002-0959-1519

uncertainty about the required organizational and technological capabilities (Schumacher et al., 2016). The transition to Industry 4.0 requires appropriate strategies and organizational models, which may result in radical changes in business practices (Gilchrist, 2016).

To understand and facilitate their transition to Industry 4.0, organizations must develop own strategic roadmaps that define their development directions (Ghobakhloo, 2018). While digital transformation (DT) has several potentials, many companies struggle with its implementation (Ghobakhloo and Fathi, 2019). This difficulty is especially true for SMEs that often face limited digitalization level, lack of time, resources and flexibility (Lassnig et al., 2022; Löfving et al., 2014; Schröder, 2016). Despite the fact that they can significantly improve their competitiveness, SMEs face significant challenges when adopting Industry 4.0 technologies (Sommer, 2015; Ganzarain and Errasti, 2016; Horvath and Szabo, 2019, Mittal et al., 2018).

In our research we focus on the exploration of SMEs practices in the field of Industry 4.0 implementation in Easter European economies. The purpose of this paper is to investigate the implementation of two well-established scientific models on Industry 4.0 implementation. Our study is based on the Digital Readiness Level 4.0 (DRL) model developed specifically for SMEs (Pirola et al., 2019) and the Technology-Organization-Environment (TOE) framework (Tornatzky et al., 1990).

We are trying to address the following research questions concerning SMEs of Eastern European country like Serbia.

RQ1: Are DRL and TOE appropriate for Industry 4.0 implementation in SMEs?

RQ2: Is there any additional factors that influence Industry 4.0 implementation that are not stated in DRL and TOE models?

The rest of the work is structured as follows: Section 2 reviews the literature, and Section 3 outlines the research method chosen for the study. Section 4 presents the findings, while section 5 discusses the results and their implications. Section 6 concludes with limitations and suggestions for future research.

2. LITERATURE REVIEW

2.1. The theoretical framework

Industry 4.0 is a basic element of the industrial digital transformation with the primary aim of connecting different devices and systems. As a result, this fourth industrial revolution introduces many new digital technologies as well as new business opportunities (Horvath and Szabo, 2019; Matt and Rauch, 2020). Industry 4.0 significantly improves product efficiency and quality while also providing flexibility and customization.

Big Data, IoT, Cloud Computing, Automation, Additive Manufacturing, Cyber Physical Systems (CPS), Augmented Reality (AR), and Artificial Intelligence (AI) are the most recognized and discussed Industry 4.0 technologies in SMEs and in the literature (Khanzode et al., 2021; Ghobakloo et al., 2022; Kim, 2022). Organizations must take advantage of all opportunities provided by data availability and integration for knowledge generation and decision support (Pirola et al., 2019). The impact of digital technologies on supply chain performance grows with participant integration and visibility (Patrucco et al., 2022). Additionally, while core processes, such as production, might be increasingly digitized in SMEs, the digitization and integration of supply chain processes with customers and suppliers must not be neglected for all enterprises (Lassnig et al., 2022). A smart factory boosts productivity by automating production management tasks and replacing tasks previously performed by workers with machines, smart sensors, and robots (Wu et al., 2016; Ramakrishna

et al., 2017). Productivity is increased by remodelling and improving the production process (Fragapane et al., 2020). Industry 4.0 can and will affect any company that makes decisions based on data (Saad et al, 2021). Industry 4.0 has also been suggested as a potential solution for the development of socially responsible business practices (Bienhaus and Haddud, 2018; Morrar et al., 2017; Wellener et al., 2019; Asokan et al., 2022). All of these aforementioned provide a need for research in digital readiness evaluation and challenges for digitalization implementation (Chonsawat and Sopadang, 2020). Among other researchers Brozzi et al., 2021 developed a set of Key Readiness Indicators (KRI), deepening the interpretation of the overall digital level of the companies with focus on the digital readiness of companies in terms of strategy, technological requirements, awareness about digital trends, and competences of employees. According to Kumar et al. (2020), the biggest obstacle to the adoption of I4.0 technologies is the lack of enthusiasm from partners and customers, and the primary effect group challenge for ethical and sustainable operations is the fear of I4.0 technology failure. Within literature review research Grufman et al., 2020, found that the main challenges proved being of organizational nature: SMEs need help with company-specific strategies for implementing Industry 4.0; and SMEs need skilled employees and the opportunities are flexibility and openness to innovation, which are pertinent to SMEs. Genest and Gemache, 2020 in their literature review paper find out that in 73% of analysed papers challenges are connected with lack of knowledge, 64% with business strategy and 45% with financial capacity.

Because SMEs account for nearly 99% of all companies in Europe (Matt et al., 2020), it is critical to investigate their role in Industry 4.0 participation. According to some of the researchers, there are numerous barriers to the implementation of Industry 4.0 and digitalization in SMEs (Sommer, 2015; Ganzarain and Erasti, 2016), including a lack of resources (both financial and technical), a methodology and process model, and an action plan for digitalization implementation using software to improve performance by analyzing data (Lee et al., 2015). Furthermore, there is a scarcity of research studies on Industry 4.0 implementation in SMEs, particularly in developing countries (Gross et al., 2022; Ghobakloo et al., 2022).

2.2. The research gap

The majority of the research has primarily focused on large companies in developed countries, with a small portion dealing with research in SMEs and an even smaller portion dealing with research in emerging and developing countries (Gross et al., 2022; Ghobakloo et al., 2022). Small and medium-sized enterprises (SMEs) in emerging and developing economies have much less access to capital and technology and rely more on manual processes (Coad and Tamvada, 2012; Jankulovic and Skoric, 2013).

SMEs may face compelling survival challenges if they are not properly integrated into the broader industrial context that Industry 4.0 is assuming, especially in an uncertain environment. SME leaders urgently need to adapt to the upcoming digital age to avoid losing intellectual property and competitive advantage (Kamble et al., 2018a; Dutta et al., 2020; Raj et al., 2020; Snieska et al., 2020). On the other hand, SMEs play important role in economies of each country especially emerging and developing ones. Given all of these issues, it is critical for SMEs and national economies to conduct research on digitalization as a part of Industry 4.0 implementation and their readiness for implementation in different sectors (Abdallah et al., 2022).

According to literature research paper with a more western perspective of Grufman et al., (2020), future research can be directed to readiness level for Industry 4.0 that can be used in practice for specific SMEs in different industries and different countries. Suggestion is to execute the readiness assessment on the national level by using a case study as a method. Raj

et al., (2020) in their literature research paper reported that the majority of researchers agree that the investigation of barriers related to implementation of Industry 4.0 remains largely unexplored in the literature and merits further investigation (de Sousa Jabbour et al., 2018a, b; Kamble et al., 2018a; Horváth and Szabó, 2019; Oesterreich and Teuteberg, 2016; Xu et al., 2018). Horváth and Szabó (2019) and Kamble et al. (2018b) suggest that the adoption of Industry 4.0 in the context of developing versus developed economies needs further investigation. Horváth and Szabó (2019) propose to analyse Industry 4.0 through a geographical lens, in order to compare similarities and differences across regions. Researchers find out different barriers to the adoption of Industry 4.0 technologies in different countries like Romania, Hungary, Turkey (Turkes et al, 2019; Horváth and Szabó, 2019; Saatçioğlu et al., 2019).

2.3. Contribution and aim of the study

In our research we analyse implementation of DRL and TOE models for maturity and readiness assessment for SMEs regarding Industry 4.0 in Serbia as an East European economy. We explore dimensions of these two models, compare them and test their implementation on readiness for Industry 4.0. Analysing these dimensions, we try to find some new previously not mentioned factors that are important for Industry 4.0 implementation. By researching those influential factors, we aim to explore obstacles for implementation and possible solutions for a more successful application of technologies on the path to Industry 4.0. Contribution of these paper is to widen the research of Industry 4.0 implementation factors in SMEs.

3. DATA AND METHODOLOGY

The research follows an empirical approach using the exploratory multiple case study according to Stake, 1995. The case study method enables an in-depth, multi-faceted investigation of complex issues in their real-world context, as is the case with the complex issue of digital adoption assessment in order to achieve Industry 4.0 goals. Case studies, according to Yin (2009) and Yin et al. (2018), can be used to explain, describe, or study events or phenomena in their everyday contexts.

In order to discover factors influencing the implementation of Industry 4.0 and the digital readiness of SMEs for Industry 4.0, two models TOE and DRL was chosen for implementation on different companies. These models are chosen because of their prior use in adoption analysis of Industry 4.0 technology implementation in SMEs and comparable dimensions they propose (table 1).

Table 1. Dimensions of TOE and DRL models

TOE	DRL
Technology	Technology
Organization	Strategy People Processes
Environment	Integration

Starting with a literature research on the implementation of Industry 4.0 in SMEs, the study model based on DRL and TOE was created, validated, and implemented in different case studies of SMEs from different business sectors in Republic of Serbia, each with a unique set of processes and needs for process realization. The SMEs analysed in this study operate in different business sectors, including metal profile manufacturing, sales and distribution of

construction materials, construction and selling apartments, organic crop production, wine production and higher education as a part of service industry. These companies were available for research, they are typical represent of Serbian SMEs and they showed a certain level of readiness and interest in applying new technologies of Industry 4.0. On the other hand, these case studies belong to important business sectors for the Serbian economy such as manufacturing, agriculture, construction and education. This fact is critical in understanding the sampling method used in the extensive case-study research, which was designed using a judgemental sampling approach (Eisenhardt, 1989; Hameri and Nihtilä, 1998). In contrast to random sampling, judgmental sampling is considered appropriate when resources are limited (Henry, 1990), and this sampling method is more successful in selecting the most appropriate cases for a specific research strategy (Seawright and Gerring, 2008).

3.1. The Technology-Organization-Environment (TOE)

This study employed the Technology-Organization-Environment (TOE) framework developed by Tornatzky et al., (1990), provides a more comprehensive view of technology adoption (Mohtaramzadeh et al., 2018) and incorporates both human and non-human factors. TOE is a well-known framework that is used to systematically examine the technical, organizational, and environmental factors that can influence the behaviour of SMEs when adopting Industry 4.0 technologies (Wong et al., 2019).

3.2. The Digital Readiness Level (DRL)

Pirola et al. (2019) establish DRL model designed specifically for SMEs with modularity that does not force respondents to answer all questions, even those that do not apply to their specific contexts. The model's main component is a set of questions that examine five dimensions: strategy, people, processes, technology, and integration (Table 2).

Table 2. Five dimensions of DRL model (Pirola et al., 2019)

Strategy	Analyse the company's digitalization strategy and implementation of Industry 4.0 principles.
People	Analyse people skills and how the know-how is managed inside the company
Processes	Analyse how internal processes are managed from a digitalization point of view and how data are collected, shared and managed inside the company
Technology	Analyse the current adoption of the Industry 4.0 enabling technologies
Integration	Analyse the digitalization level and the integration with other actors of the value chain

4. RESULTS AND DISCUSSION

Table 3 shows the factors that were discussed as influencing the implementation of Industry 4.0 according to previous literature research and TOE model. Factors influencing the implementation of Industry 4.0 in companies were identified through interviews and discussions in focus groups. In addition to answering questions about how they see these factors being applied, they were given the opportunity to identify some additional factors that they believe are important for the implementation of Industry 4.0. As in previous analyses, the scores for these questions were given on a scale of 1-5. Factors identified as important by respondents and not previously mentioned in the literature are denoted with **, indicating contribution of the work in the research of factors influencing application and thus possible solutions and answers for a more successful application of technologies on the path to Industry 4.0.

Table 3. Factors that influence Industry 4.0 implementation

Factors	Average
1. Technology	
1.1 Technical complexity and their cost	5.0
1.2 System integration and information flow	4.3
1.3 Digital data collection and analysis	3.5
1.4 Low cost proof of concept	3.8
1.5 Compatibility of Industry 4.0 technologies	2.7
1.6 Cybersecurity risks of Industry 4.0 technologies	1.8
1.7 Perceived benefits of Industry 4.0 technologies	4.7
1.8 User friendliness of Industry 4.0 technologies	4.7
1.9 KPI measurement using Industry 4.0 technologies **	3.8
2. Organization	
2.1 Technical resources	4.3
2.2 Financial resources	4.8
2.3 Top management support and involvement	4.0
2.4 Organizational culture and structure	3.8
2.5 Human capital	3.7
2.6 Strategic alignment and awareness of Industry 4.0	4.3
2.7 Business properties	4.5
2.8 Business process parameters volatility **	4.3
2.9 Stakeholder satisfaction – user satisfaction **	4.5
2.10 Service quality **	3.7
3. Environment	
3,1 Market dynamics and world economy	2.3
3,2 Competitive environment and pressure	3.2
3.3 Regulatory support and support programs	4.5
3.4 Stakeholder collaboration and knowledge sharing	4.3
3.5 ICT infrastructure and skilled workforce	4.2
3.6 Industry 4.0 accessibility	3.7
3.7 Shortage of workforce **	4.3

This study finds appropriate models of TOE and DRL for analysis of Industry 4.0 implementation in SMEs. It gives the results of dimensions and factors analysis of companies in one East European country like Serbia and based on research find some new factors that are important for analyzed companies. Researched case studies and the application of TOE and DRL methodologies reveal similarities between their dimensions and factors, and we obtain comparable or nearly identical outcomes. This suggests that while the Industry 4.0 process in the case studies examined in Serbian SMEs is still in its infancy, the stakeholders understand how crucial its implementation will be in the future. Analyzed SMEs are aware of the technologies and possibilities of Industry 4.0 implementation, but they are still in the early stages of identifying the best solutions and possibilities to implement, as well as identifying a road map and strategies on the path to Industry 4.0. The overall rating for the SMEs under study is supported by the result of the analysis of the state of the strategy and roadmap preparation for the implementation of Industry 4.0, which are at a low level. The influence of top management on Industry 4.0 implementation and the level of competence of management and employees are both low, which explains why SMEs are at the current level of implementation.

On the one hand, top management support and skilled managers and workers who represent willingness to change and openness to digitalization are recognized as important factors for Industry 4.0 implementation (Amaral and Pecas (2021), Schumacher et al., (2016); Ganzarain and Erasti, (2016), Khin and Kee, (2022); Ghobakhloo (2018), Erol et al., (2016)). As a result, companies must identify and hire those with the skills required to implement the Industry 4.0 strategy and their new business models. Problem-solving, optimization, analytical, big data, and cognitive abilities are becoming increasingly important in this context (Prifti et al., 2017). SMEs in Serbia are increasingly facing labour shortages and rising production costs per unit of product due to rising wages. This issue is one of the factors that will force companies to implement automation and Industry 4.0 on a larger scale and to completely change the structure of the workforce with completely new types of jobs and knowledge.

A study of SMEs in Serbia demonstrates the importance of investment factors as well as the availability of regulatory assistance, support programs, and investment funds for digitalization implementation. In relation to the issue of workers' and managers' lack of knowledge and skills in the area of Industry 4.0 technologies, research Ricci et al., (2021) suggests that collaboration with external partners (universities, research centres, system integrators, suppliers) can aid in the implementation of Industry 4.0. As a result, company shortages of skilled workers and managers can be addressed through collaboration with stakeholders and knowledge sharing with universities and research institutions.

Companies that have been analyzed have the highest level of process maturity and understanding of the importance of good process management. According to our research there exists a clear dependence of digitalization process for Industry 4.0 implementation with type of business within exact industry and with process parameters volatility. The basic performance measures that drive all other Industry 4.0 technology implementation according to our results, are the data science, data processing, data analysis and big data analytics. On the other side although it is clear that SMEs start to implement data analytics and understand importance of data management and big data technology, they do not have investment plan and strategy what to do next in further steps toward digitalization and Industry 4.0.

5. CONCLUSION

According to Gilchrist (2016)'s research, our research confirm that companies understand the importance of connecting and communicating on a horizontal and vertical level, exchanging data in real time, and making conclusions and decisions based on that data. On the other hand, the research's integrity demonstrates that companies have a low level of mutual connection and connection with the environment. As a result, companies must continue to develop their data collection and processing systems and automate them more and more with the introduction of new technologies, and this must be one of their first steps toward Industry 4.0, which is fully consistent with Amaral and Pecas's (2021) research. One of the main drivers identified in the analyzed SMEs is expected benefit confirmed also in study of Khin and Kee, 2022, which must be clearly communicated to all company managers and employees.

The need to prepare a digitization system and apply Industry 4.0 technologies in such a way that they are user friendly (element of service quality factor) for users and that their actions ensure a higher level of stakeholder engagement and user satisfaction is one of the important factors determined by this research that was not present in the researched literature. As a result, when developing a strategy, businesses and system implementers should clearly define the need for user-friendly systems that will ensure the satisfaction of all users.

Based on previously stated results it is of great importance to explore technology utilization analysis of exact business and to implement little not expensive visible

improvements that will give the results and raise the level of motivation for Industry 4.0 Implementation. Prepare the organizational culture and structure for Industry 4.0 implementation as well as human resources knowledge for ease of use user friendly new technologies.

The work's limitations are primarily related to the number of case studies processed, and future work will require applying the methodology mentioned to a larger number of companies in the business areas mentioned and testing the results obtained in other companies, industries and countries.

REFERENCES

Abdallah Y.O., Shehab, E, Al-Ashaab A (2022) Developing a digital transformation process in the manufacturing sector: Egyptian case study. Information Systems and e-Business Management 20: 613-630. https://doi.org/10.1007/s10257-022-00558-3

Amaral A, Pecas P (2021) SMEs and Industry 4.0: Two case studies of digitalization for a smoother integration. Computers in industry 125. https://doi.org/10.1016/j.compind.2020.103333

Asokan D, Huq F, Smith C (2022) Socially responsible operations in the Industry 4.0 era: post-Covid-19 technology adoption and perspectives on future research. International Journal of Operations & Production Management 42 (13): 185-217. https://doi.org/10.1108/IJOPM-01-2022-0069

Bienhaus F, Haddud A (2018) Procurement 4.0: factors influencing the digitisation of procurement and supply chains. Business Process Management Journal 24(4): 965-984. https://doi.org/10.1108/BPMJ-06-2017-0139

Brozzi, R., Riedl, M., Matta, D. (2021). Key readiness indicators to assess the digital level of manufacturing SMEs. Procedia CIRP, 96, 201-206.

Chonsawat, N., Sopadang, A. (2020). Defining SMEs' 4.0 readiness indicators. Applied sciences, 10(24), 8998.

Coad A, Tamvada J.P. (2012) Firm growth and barriers to growth among small firms in India. Small Business Economics 9(2): 383–400. https://doi.org/10.1007/s11187-011-9318-7

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Foropon, C., Godinho Filho, M. (2018b). When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors. Technological Forecasting and Social Change, 132, 18-25.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Godinho Filho, M., Roubaud, D. (2018a). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Annals of Operations Research, 1-14.

Dutta G, Kumar R, Sindhwani R, Singh R.K. (2020) Digital transformation priorities of India's discrete manufacturing SMEs – a conceptual study in perspective of Industry 4.0. Competitiveness. Review 30(3): 289–314. https://doi.org/10.1108/CR-03-2019-0031

Erol S, Schumacher A. Sihn W. (2016) Strategic guidance towards Industry 4.0 – a three-stage process model. International Conference on Competitive Manufacturing 9(1): 495-501.

Fragapane G, Ivanov D, Peron M, Sgarbossa F, Strandhagen J.O. (2020) Increasing flexibility and productivity in Industry 4.0 production networks with autonomous mobile robots and smart intralogistics. Annals of Operations Research 308: 125-143. https://doi.org/10.1007/s10479-020-03526-7

Ganzarain J, Errasti N, (2016) Three stage maturity model in SME's toward industry 4.0. Journal of Industrial Engineering Management 9(5): 1119–1128. https://doi.org/10.3926/jiem.2073

Genest, M. C., Gamache, S. (2020). Prerequisites for the implementation of industry 4.0 in manufacturing SMEs. Procedia Manufacturing, 51, 1215-1220.

Ghobakloo M, Iranmanesh M, Vilkas M, Grybauskas A, Amran A. (2022) Drivers and barriers of Industry 4.0 technology adoption among manufacturing SMEs: a systematic review and transformation roadmap. Journal of Manufacturing Technology Management 33(6): 1029-1058. https://doi.org/10.1108/JMTM-12-2021-0505

Gilchrist, A (2016) Industry 4.0: The Industrial Internet of Things. Apress, Berkeley, CA.

Gross O, Presser M, Tambo T, (2022) Surround yourself with your betters: Recommendations for adopting Industry 4.0 technologies in SMEs. Digital Business, 2(2). https://doi.org/10.1016/j.digbus.2022.100046

Grufman, N., Lyons, S., Sneiders, E. (2020). Exploring readiness of SMEs for industry 4.0. Complex Systems Informatics and Modeling Quarterly, (25), 54-86.

Eisenhardt K.M. (1989) Building theories from case study research. The Academy of Management Review 14(4): 532-550. https://doi.org/10.2307/258557

Hameri A.P., Nihtilä, J, (1998) Product data management – exploratory study on state-of-the-art in one-of-a-kind industry. Computers in Industry 35(3): 195-206. https://doi.org/10.1016/S0166-3615(98)00064-5

Henry G.T. (1990) Practical Sampling. Sage. Thousand Oaks, CA.

Horvath D, Szabo R.Z. (2019) Driving forces and barriers of Industry 4.0: do multinational and small and medium-sized companies have equal opportunities? Technological Forecasting and Social Change 146: 119–132, https://doi.org/10.1016/j.techfore.2019.05.021

Jankulovic A, Skoric V, (2013), Performance management system implementation in a Southeast European transition economy, Journal for East European Managament Studies, 18 (2): 173-190.

Kamble S, Gunasekaran A, Arha H, (2018a) Understanding the Blockchain technology adoption in supply chains-Indian context. International Journal of Production Research 57(9): 1–25. https://doi.org/10.1080/00207543.2018.1518610

Kamble S.S., Gunasekaran A., Gawankar S.A. (2018b) Sustainable Industry 4.0 framework: a systematic literature review identifying the current trends and future perspectives. Process Safety and Environmental Protection 117: 408–425. https://doi.org/10.1016/j.psep.2018.05.009

Khanzode A.G., Sarma P.R.S., Mangla S.K., Yuan, H. (2021) Modeling the industry 4.0 adoption for sustainable production in micro, small and medium enterprises. Journal of Cleaner Production, 279. https://doi.org/10.1016/j.jclepro.2020.123489

Khin S, Kee D,M.H. (2022) Factors influencing industry 4.0 adoption. Journal of Manufacturing Technology Management 33(3): 448-467. https://doi.org/10.1108/JMTM-03-2021-0111

Kim H. (2022) Performance from building smart factories of small-and-medium sized enterprises: the moderating effects of product complexity and company size. International Journal of Operations & Production Management 42(10): 1497-1520. https://doi.org/10.1108/IJOPM-10-2021-0654

Kumar, R., Singh, R. K., Dwivedi, Y. K. (2020). Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges. Journal of cleaner production, 275, 124063.

Lassnig, M., Müller, J. M., Klieber, K., Zeisler, A., Schirl, M. (2022). A digital readiness check for the evaluation of supply chain aspects and company size for Industry 4.0. Journal of Manufacturing Technology Management, 33(9), 1-18.

Lee J, Bagheri B, Kao H.A. (2015) A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manufacturing Letters 3: 8-23. https://doi.org/10.1016/j.mfglet.2014.12.001

Löfving M, Säfsten K, Winroth M. (2014) Manufacturing strategy frameworks suitable for SMEs. Journal of Manufacturing Technology Management 25(1): 7-26. https://doi.org/10.1108/JMTM-08-2012-0081

Matt D.T., Rauch E. (2020) SME 4.0: The Role of Small- and Medium-Sized Enterprises in the Digital Transformation. In: Matt D, Modrák V, Zsifkovits H. (eds) Industry 4.0 for SMEs. Palgrave Macmillan. Cham, 3-36. https://doi.org/10.1007/978-3-030-25425-4_1

Mittal S, Khan M.A., Romero D, Wuest T. (2018) A critical review of smart manufacturing & Industry 4.0 maturity models: implications for small and medium-sized enterprises (SMEs). Journal of. Manufacturing Systems 49(1): 194–214. https://doi.org/10.1016/j.jmsy.2018.10.005

Morrar R, Arman H, Mousa S. (2017) The Fourth industrial revolution (industry 4.0): a social innovation perspective. Technology Innovation Management Review 7(11): 12-20. https://doi.org/10.22215/timreview/1117

NALED, SME sector crucial for the development of the Serbian economy. https://naled.rs/en/blog-msp-sektor-kljucan-za-razvoj-srpske-ekonomije-246. Accesed 17 february 2023.

Oesterreich, T. D., Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in Industry, 83, 121-139

Patrucco A, Trabuchhi D, Golini R. (2022) How do Industry 4.0 technologies boost collaborations in buyer-supplier relationships? Research-Technology Management 65(1): 48-58. https://doi.org/ 10.1080/08956308.2021.1999131

Pirola F, Cimini C, Pinto R. (2019) Digital readiness assessment of Italian SMEs: A case study research. Journal of Manufacturing Technology Management 31(5): 1045-1083. https://doi.org/10.1108/JMTM-09-2018-0305

Prifti L, Knigge M, Kienegger H, Krcmar, H. (2017) A competency model for 'Industrie 4.0' employees. 13th International Conference on Wirtschaftsinformatik, St Gallen, CH.

Raj A, Dwivedi G, Sharma A, de Sousa Jabbour A.B.L., Rajak S. (2020) Barriers to the adoption of industry 4.0 technologies in the manufacturing sector: an intercountry comparative perspective. International Journal of Production Economics 224. https://doi.org/10.1016/j.ijpe.2019.107546

Ramakrishna S, Khong T.C., Leong, T.K. (2017) Smart manufacturing', Procedia Manufacturing 12: 128-131. [online] https://doi.org/10.1016/j.promfg.2017.08.01

Ricci R, Battaglia D, Neirotti P. (2021) External knowledge search, opportunity recognition and Industry 4.0 adoption in SMEs. International Journal of Production Economics 240. https://doi.org/10.1016/j.ijpe.2021.108234

Saad S, Bahadori R, Jafarnejad H. (2021) The smart SME technology readiness assessment methodology in the context of Industry 4.0. Journal of Manufacturing Technology Management 32(5): 1037-1065. https://doi.org/10.1108/JMTM-07-2020-0267

Saatçioğlu, Ö. Y., Özispa, N., Kök, G. T. (2019). Scrutinizing the Barriers That Impede Industry 4.0 Projects: A Country-Wide Analysis for Turkey. In Agile Approaches for Successfully Managing and Executing Projects in the Fourth Industrial Revolution (pp. 294-314). IGI Global.

Seawright J, Gerring J. (2008) Case selection techniques in case study research: a menu of qualitative and quantitative options. Political Research Quarterly 61(2): 294-308. https://doi.org/10.1177/1065912907313077

Snieska V, Navickas V, Haviernikova K, Okręglicka M, Gajda W. (2020) Technical, information and innovation risks of industry 4.0 in small and medium-sized enterprises–case of Slovakia and Poland. Journal of Business Economics & Management 21(5): 1269–1284. https://doi.org/10.3846/jbem.2020.12279

Sommer L. (2015) Industrial revolution-industry 4.0: are German manufacturing SMEs the first victims of this revolution?. Journal of Industrial Engineering Management 8(5): 1512–1532. https://doi.org/10.3926/jiem.1470

Schröder C. (2016) The Challenges of Industry 4.0 for Small and Medium-Sized Enterprises. Friedrich- Ebert-Stiftung, Bonn.

Schumacher A, Erol S, Sihn, W. (2016) A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Procedia CIRP 52: 161–166. https://doi.org/10.1016/j.procir.2016.07.040

Stake RE. (1995) The art of case study research. London: Sage Publications Ltd. ISBN: 9780803957671

Tornatzky L. G., Fleischer M, Chakrabarti A. K. (1990) The process of technological innovation. Lexington, MA: Lexington Books. ISBN: 9780669203486

Turkeș, M. C., Oncioiu, I., Aslam, H. D., Marin-Pantelescu, A., Topor, D. I., Căpușneanu, S. (2019). Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania. Processes, 7(3), 153.

Venkatesh Viswanath, Morris, Michael G, Davis, Gordon B, Davis, Fred D. (2003) User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly. 27(3): 425–478. https://doi.org/10.2307/30036540

Wellener P, Shepley S, Dollar B, Laaper S, Manolian H.A., Beckoff D. (2019) Deloitte and MAPI smart factory study. Deloitte Insights.

Wong L, Leong L, Hew J, Tan G, Ooi K. (2019) Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. International Journal of Information Management 52. https://doi.org/10.1016/j.ijinfomgt.2019.08.005

Wu L, Yue X, Jin, A., Yen, D.C. (2016) Smart supply chain management: a review and implications for future research. The International Journal of Logistics Management 27(2): 395-417. https://doi.org/10.1108/IJLM-02-2014-0035

Xu, L. D., Xu, E. L., Li, L. (2018). Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941-2962.

Yin R.K. (2009) Case study research, design and method. 4.th edition London: Sage Publications Ltd. ISBN: 1412960991

Yin, R. K., Campbell D. T. (Donald Thomas 1916-1996 writer of forward), (2018) Case study research and applications: design and methods. 6.th edition Thousand Oaks California: SAGE Publications Inc. ISBN: 9781506336169