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Current Perspectives on Development of Industry 4.0 in Logistics of Machinery and Equipment Industry in Slovakia

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Abstract: The aim of the paper was to evaluate the current situation of Industry 4.0 in logistics in the machinery and equipment industry in Slovakia. The intention of the paper was to fill a research gap in the form of identification and analysis of the studied issue in the selected industry in Slovakia. The identification and analysis of the subject issue were conducted in 57 enterprises in the machinery and equipment industry in Slovakia. The results of the investigated issues were interpreted through descriptive and inferential statistics. The research instrument was a questionnaire, which involved a construction of several types of questions. The results of the testing showed that enterprises with different numbers of employees perceive, implement and use Industry 4.0 technologies in logistics. Also, based on the statistical hypothesis testing, it was confirmed that big data and the Internet of Things are the most used of the Industry 4.0 technologies in the selected logistics processes. The connection between Industry 4.0 and Logistics 4.0 will be an increasingly dominant theme as the Fourth Industrial Revolution represents a change that almost every enterprise in the world is going through or will go through.

Keywords: Digitization, Industry 4.0, the fourth industrial revolution, Logistics 4.0

1. Introduction

Every enterprise seeks to introduce new technologies to improve the quality, efficiency and effectiveness of resources, to reduce risks, and remain competitive in the marketplace [1,2]. Technologies in the 21st century heavily rely on science, combining knowledge from more diverse fields (higher originality) and becoming longer cycled but having impact onless diverse fields (lower generality) [3].

Industry 4.0 is increasingly being promoted as the key to increasing productivity, driving economic growth, and ensuring business sustainability. The impact of Industry 4.0 is noticeable in business processes and business areas, where it represents a response to the trend towards digitization of industry. Changes are also taking place in corporate logistics, where the new concept of Logistics 4.0 is emerging. Industry 4.0 is revolutionising logistics by leveraging data and analytics in smart manufacturing, making it a key element of any organisation's performance. The First Industrial Revolution was a period of fundamental transcontinental change, characterised by a complex combination of socio-economic practices and innovation. The key features of the Second and Third Industrial Revolutions demonstrate that the socio-economic transformations that took place in these periods were indeed industrial revolutions [4]. The Fourth Industrial Revolution, also referred to as Industry 4.0, determines changes especially in the field of manufacturing, where there is a shift from mass production to personalised production, which leads to greater flexibility in production processes [5].

2. Theoretical Framework

Industry 4.0 is synonymous with the Fourth Industrial Revolution, which was preceded by the use of innovations such as steam power, cotton spinning, and railways (First Industrial Revolution), the enabling of mass production through assembly lines and electricity (Second Industrial Revolution), and the automation of production lines through electronic systems and computer technology (Third Industrial Revolution) [6]. The concept of Industry 4.0 represents the Fourth Industrial Revolution, which is defined as a new level of organisation and control over the entire value chain of the product lifecycle and is focused on increasingly individualised customer requirements [7]. Industry 4.0 involves the adoption of industrial automation systems to support the management of value and supply chains and more broadly manage all related processes [8,9]. Porubčinová and Fidlerová suppose the essence of Industry 4.0 in the interconnection of individual technological components, with people, machines, equipment and products interacting with each other [10]. Industry 4.0 offers above all a new vision of the functioning of production, service delivery, asset management, and the conduct of business activities [11]. Industry 4.0 is characterised by the intelligent, horizontal and vertical interconnection of people, machines, objects, and information and communication technology systems. The future of value creation is thus to be found in digitised, intelligent, connected and autonomous factories and production networks capable of operating in real time. Industry 4.0 will bring increased efficiency, quality, and flexibility [12,13]. Industry 4.0 brings together different technological approaches and models. These include artificial intelligence, digital twins, blockchain and cloud computing [14], which aim to accelerate computerization and connectivity across industries, leading to operational excellence [15]. All these elements are interconnected and are

essential to achieve the prosperity of the whole society [16]. Industry 4.0 focuses on building smart factories and smart manufacturing. The goal of Industry 4.0 is to create smart products and processes that place greater emphasis on the Internet of Things and control logic. Industry 4.0 assumes that labour costs will be reduced through smart technology [17]. Industry 4.0 aims to achieve higher levels of operational and production efficiency through higher levels of automation [18]. The Fourth Industrial Revolution, also labelled Industry 4.0, was begotten with emergent and disruptive intelligence and information technologies. These new technologies are enabling ever-higher levels of production and logistics efficiencies [19]. Industry 4.0 has evolved thanks to the revolution in information and communication technologies. This technological change has taken place through the Internet of Things and the Internet of Services, making industry intelligent with the help of cyber-physical systems [20]. Through Industry 4.0 technologies, enterprises will achieve sustainable goals in the form of improved work environment, work performance, reduced production process time, improved product quality [21]. We are currently witnessing a different number of Industry 4.0 technologies according to researchers, scholars, and surveys from practitioners. These are advanced information and communication technologies such as additive manufacturing, augmented reality, autonomous robots, big data and analytics, cloud computing, blockchain, Internet of Things [22-24]. Industry 4.0 combined with the Internet of Things and Service, Cyber Physical Systems, Cloud Computing, and Big Data has the potential to enhance industry performance, make new products, and spark ingenious business models. Industry 4.0 includes big data, industrial automation, simulation, integration systems, the Internet of Things, cybersecurity, cloud computing, additive manufacturing, and augmented reality. These technologies are the main drivers of technology work aimed at continuous improvement [25]. Artificial Intelligence and 5G connectivity are seen as drivers of Industry 4.0, accelerating the blurring of the boundaries between the digital, biological, and physical spheres through new technologies such as blockchain, gene editing, IoT sensors, nanotechnology, or 3D printing [26].

The intensification of competition in supply chains has forced enterprises to transform their logistics to a smart level. In a smart logistics system, logistics processes are more flexible, intelligent, and agile; therefore, they are well equipped to meet the challenges of a dynamic and global market [27]. In line with the demanding industry, the fourth wave of technological innovation, known as Industry 4.0 in logistics and supply chain as Logistics 4.0, has materialised as a result of the digital transformation of industrial markets integrated with smart technologies [28]. The term Industry 4.0 is also inherently linked to the concepts of smart logistics and Logistics 4.0. These terms refer to the use of logistics in connection with cyber-physical systems and the Internet of Things. The main benefits of Logistics 4.0 are in the areas of resource planning, warehouse management systems, transport management systems, intelligent transport systems, and information security [29]. The

Industry 4.0 transition to logistics and supply chains and its extension to logistics processes and activities has been identified by Haddud et al. [30] and Ben-Daya et al. [31]. Logistic 4.0 as a concept is based on these same principles and refers to logistics management defined by interconnection, digitalization of information, and cloud-based computer applications [32]. Strandhagen et al. [33] described Logistics 4.0 using the following characteristics: real-time analysis of big data, reduced need for warehousing due to new manufacturing techniques, autonomous robots with tracking and decision-making systems that lead to optimized inventory control, real-time information exchange, and no information disruption due to smart items. Logistics 4.0 is the use of Cyber-Physical systems (CPS) that monitor and control the physical processes, usually with feedback [34]. Logistics 4.0 integrates different types of technologies to increase supply chain efficiency, shift the attention of organizations to value chains, maximise the value provided to both consumers and customers by increasing the level of competitiveness [35]. Logistics 4.0 is defined as intelligent logistics because its components enable processes to be managed intelligently. The components of Logistics 4.0 are: automatic identification, real-time location determination, automatic data collection, connection and integration, data processing and analysis, business services [36]. Verma et al. [37] define the term smart logistics, which includes providing real-time movement in the flow of materials, better material handling, and accurate risk management by integrating CPS and IoT in logistics.

3. Research Methodology

The objective of the paper was to evaluate the current situation of Industry 4.0 in logistics in the machinery and equipment industry in Slovakia. The paper aimed to fill a research gap in the form of identification and analysis of the studied issue in the selected industry in Slovakia, as there are very few studies and research that deal with this issue. The paper provides a literature review on Industry 4.0 in relation to Logistics 4.0. The paper also contains the results of a survey conducted by questionnaire in spring 2021. The research task presented in the paper was to specify the Fourth Industrial Revolution in the form of Industry 4.0 in the enterprise area - logistics in a selected industry in Slovakia. Based on these facts and also on the main objective of the paper, the following hypotheses were established:

H_{0a}: We assume that there is no statistically significant difference between Industry 4.0 technologies in logistics and business size.

H_{1a}: We assume that there is a statistically significant difference between Industry 4.0 technologies in logistics and business size.

H_{0b}: We assume that there is no statistically significant difference between the use of Industry 4.0 technologies in the logistics process of warehousing and transportation.

H_{1b}: We assume that there is a statistically significant difference between the use of Industry 4.0 technologies in the logistics process of warehousing and transportation.

The source of background knowledge presented in the theoretical part of the paper was professional foreign literature and journals indexed in international databases. In this part of the paper, a literature review was conducted using comparative analysis. The results of the review were interpreted through the results of the questionnaire survey. The research instrument was a questionnaire that consisted of different types of questions. Selected data from the questionnaire survey which were related to the machinery and equipment industry were presented in this paper. The data were interpreted through a frequency table, pie charts, and a radar chart. The hypotheses established were tested through the non-parametric Mann-Whitney U test.

The research sample consisted of 57 enterprises operating in the machinery and equipment industry in the Slovak Republic. Mainly large enterprises (250 or more persons employed) were involved in the survey. Their percentage share was 87.72%. The analysis by legal form of the enterprise was also used to categories' the enterprises surveyed. Based on the collected data, the survey involved the largest percentage (80.70%) of limited liability companies from the Slovak machinery and equipment industry. The surveyed enterprises that indicated the legal form of a joint stock company reached a share of 19.30%.

The Slovak Republic is divided into 8 regions. According to the administrative division of Slovakia, machinery and equipment enterprises from the Bratislava Region participated in the survey with the largest percentage share (22.81%). Machinery and equipment enterprises located in Žilina Region also had a high percentage (19.30%) of participation in the survey. The next respondents were from Trnava Region (17.54%), Trenčín Region (15.79%), Nitra Region (8.77%), and Košice Region (7.02%). The lowest number of respondents who participated in the survey were from the Banská Bystrica Region (3.51%) and the Prešov Region (5.26%).

4. Research Results

In the following part of the paper, the identified facts related to the development of logistics in the Industry 4.0 environment in machinery and equipment enterprises in Slovakia were analysed. Within the selected summarised responses, we gathered from the respondents that 63.16% of machinery and equipment enterprises in Slovakia are sufficiently informed about Industry 4.0. and 29.82% have partial information about the Fourth Industrial Revolution (Industry 4.0). 7.02% of the respondents stated that they do not have enough information about Industry 4.0 and digitization of the enterprise. None of the surveyed enterprises confirmed that they did not have any information regarding the ongoing Fourth Industrial Revolution.

Industry 4.0 is changing the way every business operates through the Internet of Things, smart devices and technologies that communicate with each other through cyber-physical systems. The state of implementation of Industry 4.0 in logistics was investigated in machinery and equipment enterprises in Slovakia. Based on the responses obtained, it was found that 33.33% of the surveyed enterprises have implemented Industry 4.0 in logistics, while 50.88% of the surveyed enterprises are currently implementing Industry 4.0 in logistics. In the machinery and equipment industry enterprises in Slovakia, 15.79% of the respondents are considering the implementation of Industry 4.0 in logistics. None of the enterprises surveyed stated that they were not considering the implementation of Industry 4.0 in logistics.

Industry 4.0 significantly affects not only individual business areas, but also processes. Logistics processes are no exception. In the context of the application of Industry 4.0 in the logistics of machinery and equipment enterprises, we wanted to know which selected logistics processes are under the greatest influence of Industry 4.0. From the obtained data we can conclude that the logistics process warehousing (28.07%) is the most influenced by Industry 4.0. The logistics process of transportation (24.57%) has also reached a high percentage and so has the logistics process of packaging (21.05%). The next was inventory management (14.03%) and logistics communication (8.77%). The logistics process of purchasing is the least (3.51%) under the influence of Industry 4.0. At the same time, we wanted to know from the respondents which of the selected logistics processes will have to be changed in the near future due to the ongoing digitalisation. Machinery and equipment enterprises want to change inventory management the most. This process reached a share of 26.32%. The logistics process of packaging also received a high percentage share of 19.30% and so did the logistics process of warehousing (17.54%). The next in order, as determined by the survey results, were transportation (15.78%) and purchasing (14.04%). According to the respondents, the logistics communication will have to change the least (7.02%), which will not change significantly under the influence of digitalisation.

Based on the evaluation of the data, the most used of the Industry 4.0 technologies by enterprises is big data (36.85%). A high percentage (24.56%) was also achieved by the use of the Internet of Things. The next in the rank order of Industry 4.0 technologies were cloud computing (16%), additive manufacturing (10.53%) and augmented reality (5.26%), according to the results. Machinery and equipment enterprises use artificial intelligence and autonomous robots the least in logistics. These Industry 4.0 technologies reached an identical percentage (3.51%). Digitalisation is fundamentally changing the way every business operates. Logistics is no exception, so we wanted to know which of the selected Industry 4.0 technologies are planned to be used to a greater extent in logistics within the next 5 years. Machinery and equipment enterprises plan to concentrate on the use of additive manufacturing (28.07%). Also, respondents want to concentrate on the implementation of

autonomous robots (26.32%) in logistics. Other Industry 4.0 technologies in the order assigned to them by machinery and equipment enterprises included artificial intelligence (14.04%), augmented reality (12.28%), and Internet of Things (10.53%). Respondents plan the least to concentrate on big data (5.26%) and cloud computing (4%).

With the era of Industry 4.0, job losses in logistics processes are also on the rise. We were interested whether the surveyed enterprises will eliminate logistics jobs due to the implementation of Industry 4.0 technologies. From the answers, we were informed that 57.89% of enterprises will change logistics jobs. An interesting opinion is that 31.58% of the respondents will partially reduce the number of logistics jobs. This can be explained by the fact that enterprises will move their employees to other departments and other positions that will not be fully digitalised and will need to use human labour. Only 10.53% of the surveyed enterprises will not change jobs in logistics.

The combination of the research sample according to the use of Industry 4.0 technologies in logistics in the regions in Slovakia is shown in Figure 1. From the results in the form of averages, we conclude that additive manufacturing is mostly applied in the Košice Region (4.50). Augmented reality is most used by respondents in the Trnava Region (4.22). Internet of Things and big data are most used in the Nitra Region. Both Industry 4.0 technologies achieved an average of 5.50. Artificial intelligence is used equally in the Bratislava Region and the Košice Region. In both regions it reached an average value of 2.00. Autonomous robots took the first place with an average value (3.50) of use in the Košice Region. Also in Košice Region, the use of cloud computing dominates (4.50).

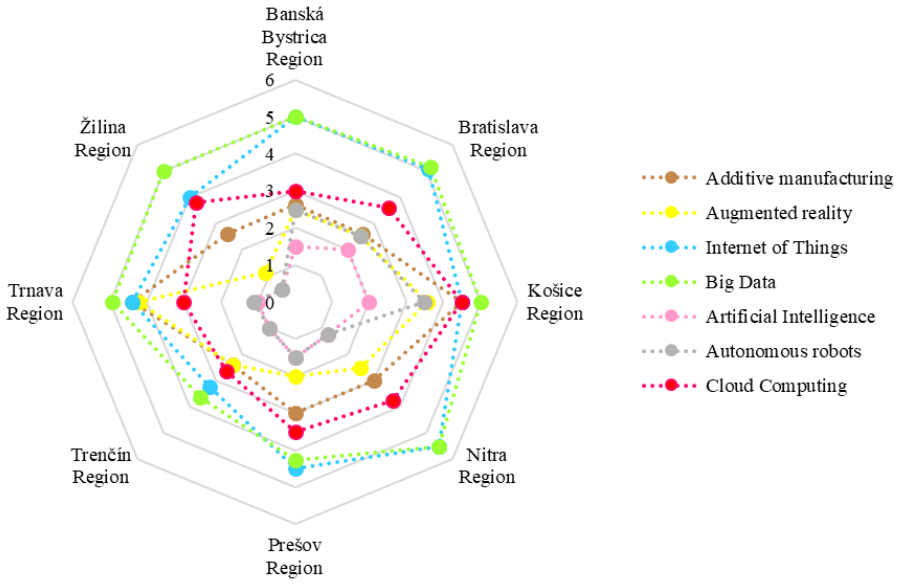


Fig. 1 Structure of respondents according to the use of Industry 4.0 technologies in logistics in regions of Slovakia. Source: author

The null hypothesis (H_{0a}) and the alternative hypothesis (H_{1a}) were tested using the Mann-Whitney U test. Based on the summary of the testing, we conclude that the significance achieved (p

= <0.001) indicates that there is a statistically significant difference between the different Industry 4.0 technologies in logistics (additive manufacturing, augmented reality, internet of things, big data, artificial intelligence, autonomous robots, cloud computing) and the business size. Based on the evaluated testing, the alternative hypothesis is accepted.

The non-parametric Mann-Whitney U test was used to test the hypothesis (H_{0b} and H_{1b}). Based on the significance (p = 0.006) achieved, we conclude that there is a statistically significant difference between the use of the Internet of Things and the logistics processes of warehousing and transportation. Also, the significance achieved (p = 0.009) indicates that there is a statistically significant difference between the logistics processes of warehousing and transportation and Industry 4.0 - Big Data technology. For the other Industry 4.0 technologies, the hypothesis was not confirmed.

5. Discussion

The research task was to identify and subsequently analyse the impact of Industry 4.0 in the logistics of the machinery and equipment industry in Slovakia. Currently, there is no foreign or domestic research that would indicate the importance of Industry 4.0 in logistics in the machinery and equipment industry. There are many theoretical scientific papers that review the literature on Industry 4.0 in logistics, but they do not speak about the real situation in the form of research in the industry. We tried to fill this gap and a survey was conducted in the selected industry to investigate the fourth industrial revolution in logistics management. Based on the findings and the data evaluated, we came to the following facts. 12.28% of medium-sized enterprises and 87.72% of large enterprises participated in the questionnaire survey. Within the selected summarised responses, we gathered from the respondents that 63.16% of machinery and equipment enterprises are sufficiently informed about Industry 4.0. From the responses of the surveyed enterprises, we collected that 50.88% of the respondents are implementing Industry 4.0 in logistics. From the data obtained, we can conclude that the logistics process of warehousing (28.07%) is the most under the influence of Industry 4.0. Machinery and equipment enterprises want to change inventory management the most because of the ongoing digitalisation. Among the Industry 4.0 technologies, enterprises are using big data in logistics the most (36.85%). Within the next five years, machinery and equipment enterprises plan to concentrate on the use of additive manufacturing (28.07%). From the responses, we learnt that 57.89% of enterprises will change jobs in logistics. The use of Industry 4.0 technologies in logistics in Slovak regions is differentiated. More used in Slovak regions is the Internet of Things and Big Data. Less used in Slovak regions are artificial intelligence and autonomous robots. We wanted to analyse the issue under study in depth and thus inferential statistics was used. Therefore, the non-parametric Mann-Whitney U test was applied. The results of the testing showed that enterprises with different numbers of employees perceive, implement and use Industry 4.0 technologies in logistics.

Also, based on the statistical hypothesis testing, it was confirmed that Big Data and the Internet of Things are the most used of the Industry 4.0 technologies in the selected logistics processes. This is also confirmed by the results from descriptive statistics.

6. Conclusion

Industry 4.0 is increasingly being promoted as the key to increasing productivity, supporting economic growth, and ensuring business sustainability. The impact of Industry 4.0 can be seen in business processes and business areas, where it is a response to the trend towards digitalisation of industry. Changes are also taking place in corporate logistics, where a new concept of Logistics 4.0 is emerging. This represents a new level of logistics in the form of implementation and use of smart technologies in line with the requirements of Industry 4.0. It is important for every enterprise to understand the characteristics and content not only of Industry 4.0 but also of new terms such as Logistics 4.0, because the most significant transformation is taking place in production and logistics. Logistics 4.0 is redefining logistics jobs and the use of technology and equipment in line with the basic requirements set for Industry 4.0. The connection between Industry 4.0 and Logistics 4.0 will be an increasingly dominant theme as the Fourth Industrial Revolution represents a change that almost every enterprise in the world is going through or will go through.

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References

[1] Falk, M., Klien, M. & Schwarz, G. (2015). Large manufacturing firms plan to increase their investments in 2015. Results of the wifo spring 2015 investment survey. WIFO Monatsberichte (monthly reports), 88(7), 581–591. Retrieved October 2, 2021, from https://www.wifo.ac.at/en/publications/search_for_publications?detail-view=yes&publikation_id=58253

[2] Tassey, G. (2014). Competing in Advanced Manufacturing: The Need for Improved Growth Models and Policies. Journal of Economic Perspectives 28(1), 27–48. DOI: 10.1257/jep.28.1.27.

[3] Lee, J. & Lee, K. (2021). Is the fourth industrial revolution a continuation of the third industrial revolution or something new under the sun? Analyzing technological regimes using US patent data. Industrial and Corporate Change, 30(1), 137–159. DOI: 10.1093/icc/dtaa059.

[4] Moll, I. (2021). The Myth of the Fourth Industrial Revolution. Theoria, 68(167), 1–38. DOI: 10.3167/th.2021.6816701.

[5] Nosalska, K. & Mazurek, G. (2019). Marketing principles for Industry 4.0 — a conceptual framework. Engineering Management in Production and Services 11(3), 9–20. DOI: 10.2478/emj-2019-0016.

[6] Ingaldi, M. & Ulewicz, R. (2019). Problems with the Implementation of Industry 4.0 in Enterprises from the SME Sector. Sustainability 12(1), 217. DOI: 10.3390/su12010217.

[7] Vaidya, S., Ambad, P. & Bhosle, S. (2018). Industry 4.0 – A Glimpse. Procedia Manufacturing 20, 233–238. DOI: 10.1016/j.promfg.2018.02.034.

[8] Reischauer, G. (2018). Industry 4.0 as policy-driven discourse to institutionalize systemic innovation in manufacturing. Academy of Management Proceedings, 2018(1), 11435. DOI: 10.5465/ambpp.2018.11435abstract.

[9] Yin, Y., Stecke, K.E. & Li, D. (2017). The evolution of production systems from Industry 2.0 through Industry 4.0. International Journal of Production Research, 56(1-2), 848–861. DOI: 10.1080/00207543.2017.1403664.

[10] Porubčinová, M. & Fidlerová, H. (2020). Determinants of Industry 4.0 Technology Adaption and Human - Robot Collaboration. Research Papers Faculty of Materials Science and Technology Slovak University of Technology 28(46), 10-21. DOI: 10.2478/rput-2020-0002.

[11] Terziyan, V., Gryshko, S. & Golovianko, M. (2018). Patented intelligence: Cloning human decision models for Industry 4.0. Journal of Manufacturing Systems, 48, 204–217. DOI: 10.1016/j.jmsy.2018.04.019.

[12] Kagermann, H., Wahlster, W. & Helbig, J. (2013). Recommendations for implementing the strategic initiative Industrie 4.0: final report of the Industrie 4.0 working group. Communication Promoters Group of the Industry-Science Research Alliance, Acatech, Frankfurt am Main. Retrieved October 5, 2021, from https://en.acatech.de/publication/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/

[13] Müller, J.M., Buliga, O. & Voigt, K.-I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological Forecasting and Social Change 132, 2–17. DOI: 10.1016/j.techfore.2017.12.019.

[14] Ghobakhloo, M., Fathi, M., Iranmanesh, M., Maroufkhani, P. & Morales, M.E. (2021). Industry 4.0 ten years on: A bibliometric and systematic review of concepts, sustainability value drivers, and success determinants. Journal of Cleaner Production, 302, 127052. DOI: 10.1016/j.jclepro.2021.127052.

[15] Luz Tortorella, G., Cauchick-Miguel, P.A., Li, W., Staines, J. & McFarlane, D. (2021). What does operational excellence mean in the Fourth Industrial Revolution era? International Journal of Production Research, 1–17. DOI: 10.1080/00207543.2021.1905903.

[16] Surówka, M., Popławski, Ł. & Fidlerová, H. (2021). Technical Infrastructure as an Element of Sustainable Development of Rural Regions in Małopolskie Voivodeship in Poland and Trnava Region in Slovakia. Agriculture 11(2), 1-23. DOI: 10.3390/agriculture11020141.

[17] Zhou, R. & Le Cardinal, J. (2019). Exploring the Impacts of Industry 4.0 from a Macroscopic Perspective. Proceedings of the Design Society: International Conference on Engineering Design 1(1), 2111–2120. DOI: 10.1017/dsi.2019.217.

[18] Ślusarczyk, B., Tvaronavičienė, M., Ul Haque, A. & Oláh, J. (2020). Predictors of Industry 4.0 Technologies Affecting Logistic Enterprises' Performance: International Perspective from Economic Lens. Technological and Economic Development of Economy 26(6), 1263–1283. DOI: 10.3846/tede.2020.13376.

[19] Bai, C., Dallasega, P., Orzes, G. & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. International Journal of Production Economics, 229, 107776. DOI: 10.1016/j.ijpe.2020.107776.

[20] Liao, Y., Deschamps, F., Loures, E. de F.R. & Ramos, L.F.P. (2017). Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal. International Journal of Production Research 55(12), 3609–3629. DOI: 10.1080/00207543.2017.1308576.

[21] Kamble, S.S., Gunasekaran, A. & Gawankar, S.A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. Process Safety and Environmental Protection 117, 408–425. DOI: 10.1016/j.psep.2018.05.009.

[22] Dalenogare, L.S., Benitez, G.B., Ayala, N.F. & Frank, A.G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383–394. DOI: 10.1016/j.ijpe.2018.08.019.

[23] Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., Amicis, de R.B., Pinto, E., Eisert, P., Dollner, J. & Vallarino, I. (2015). Visual Computing as a Key Enabling Technology for Industrie 4.0 and Industrial Internet. IEEE Computer Graphics and Applications, 35(2), 26–40. DOI: 10.1109/mcg.2015.45.

[24] Wan, J., Cai, H. & Zhou, K. (2015). Industrie 4.0: Enabling technologies. Proceedings of 2015 International Conference on Intelligent Computing and Internet of Things. DOI: 10.1109/icaiot.2015.7111555.

[25] Lopes de Sousa Jabbour, A.B., Jabbour, C.J.C., Filho, M.G. & Roubaud, D. (2018). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. Annals of Operations Research 270(1-2), 273–286. DOI: 10.1007/s10479-018-2772-8.

[26] Krafft, M., Sajtos, L. & Haenlein, M. (2020). Challenges and Opportunities for Marketing Scholars in Times of the Fourth Industrial Revolution. Journal of Interactive Marketing 51, 1-8. DOI: 10.1016/j.intmar.2020.06.001.

[27] Zhong, R.Y., Xu, X., Klotz, E. & Newman, S.T. (2017). Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering 3(5), 616–630. DOI: 10.1016/j.eng.2017.05.015.

[28] Hasan, M.M., Jiang, D., Ullah, A.M.M.S. & Noor-E-Alam, M. (2020). Resilient supplier selection in logistics 4.0 with heterogeneous information. Expert Systems with Applications 139, 112799. DOI: 10.1016/j.eswa.2019.07.016.

[29] Barreto, L., Amaral, A. & Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. Procedia Manufacturing 13, 1245–1252. DOI: 10.1016/j.promfg.2017.09.045.

[30] Haddud, A., DeSouza, A., Khare, A. & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. Journal of Manufacturing Technology Management 28(8), 1055–1085. DOI: 10.1108/jmtm-05-2017-0094.

[31] Ben-Daya, M., Hassini, E. & Bahroun, Z. (2017). Internet of things and supply chain management: a literature review. International Journal of Production Research 57(15-16), 4719–4742. DOI: 10.1080/00207543.2017.1402140.

[32] Kodym, O., Kubáč, L. & Kavka, L. (2020). Risks associated with Logistics 4.0 and their minimization using Blockchain. Open Engineering, 10(1), 74–85. DOI: 10.1515/eng-2020-0017.

[33] Strandhagen, J.O., Vallandingham, L.R., Fragapane, G., Strandhagen, J.W., Stangeland, A.B.H. & Sharma, N. (2017). Logistics 4.0 and emerging sustainable business models. Advances in Manufacturing 5(4), 359–369. DOI: 10.1007/s40436-017-0198-1.

[34] Jazdi, N. (2014). Cyber physical systems in the context of Industry 4.0. 2014 IEEE International Conference on Automation, Quality and Testing, Robotics. 22-24 May 2014. Cluj-Napoca, Romania. DOI: 10.1109/AQTR.2014.6857843.

[35] Amr, M., Ezzat, M. & Kassem, S. (2019). Logistics 4.0: Definition and Historical Background. Novel Intelligent and Leading Emerging Sciences Conference (NILES). 28-30 October 2019. Giza, Egypt. DOI: 10.1109/NILES.2019.8909314.

[36] Wang, K. (2016). Logistics 4.0 Solution New Challenges and Opportunities, Proceedings of the 6th International Workshop of Advanced Manufacturing and Automation – IWAMA 2016. 10-11 November 2016. Manchester, UK. DOI: 10.2991/iwama-16.2016.13.

[37] Verma, P., Kushwaha, J. & Dixit, V. (2020). Risk and resilience analysis for industry 4.0 in achieving the goals of smart logistics: An overview. Proceedings of the International Conference on Industrial Engineering and Operations Management. 10-12 March 2020. Dubai, UAE. Retrieved October 6, 2021, from http://www.ieomsociety.org/ieom2020/papers/173.pdf