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Modern ICT solutions for Logistics (4.0) in manufacturing enterprises

Emergent Research Forum (ERF)

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Abstract

The concept of Logistics 4.0 is an effect of the fourth industrial revolution (Industry 4.0). It means that the use of Information and Communication Technologies (ICT) in logistics has become unavoidable. The emergence of Logistics 4.0 promotes new challenges in logistics activity, especially for the manufacturing enterprises to increase their efficiency and effectiveness in management performance. In this paper, the poll study is presented to reflect on the possible use of modern ICT solutions for logistics in Polish and German micro, small and medium enterprises. This will allow for the continuous improvement of the idea of Logistics 4.0 in practice and will indicate the directions of future research in this area.

Keywords

ICT solutions, Logistics 4.0, Industry 4.0, micro, small, and medium manufacturing enterprises.

Introduction

Logistics trends are evolving with the fourth industrial revolution (Industry 4.0), as logistics is strictly subject to all industrial and economic changes. Thus, within Industry 1.0 (1700-1800), Logistics 1.0 was based on the mechanization of transport. Industry 2.0 (1800-1969) developed Logistics 2.0 focused on the automation of handling systems. In Industry 3.0 (1969-2011), the logistics management system in Logistics 3.0 was shaping. Finally, during Industry 4.0 (2011-now), Logistics 4.0 was created based on advanced ICT solutions (Glistau and Machado 2018). Logistics 4.0 appeared as a result of the application of Industry 4.0 technologies and technological concepts to logistics processes (Bigliardi et al. 2021). Logistics 4.0 is based on the growing importance of systems connecting the physical and cyber worlds and uses highly advanced digital technologies.

Literature positions on Logistics 4.0 highlight its immature by indicating only the theoretical and conceptual approaches (Paksoy et al. 2020). It seems that the Logistics 4.0 concept is emerging with digital technologies involved in its processes to ensure better efficiency and effectiveness (Bag et al. 2020). Logistics 4.0 is defined as “*the logistical system that enables the sustainable satisfaction of individualized customer demands without an increase in costs and supports this development in industry and trade using digital technologies*” (Winkelhaus and Grosse 2020). Also, the paradigm of Logistics 4.0 is stated as “*the optimization of inbound and outbound logistics which must be supported by intelligent systems, embedded in software and databases from which relevant information is provided and shared through Internet of Things (IoT) systems, in order to achieve a major automation degree*” (Barreto et al. 2017).

This innovative concept of logistics uses ICT solutions such as Big Data, Internet of Things, Cloud Logistics, Autonomous Logistics, 3D Printing, Robotics and Automation, Low-Cost Sensor Technology, Real-Time Data, Artificial Intelligence, Omnichannel, etc. (Magruk 2016; Szymańska et al. 2017). These innovative solutions can be used in all logistics processes (Bajdor 2017). DHL (2020/21) has listed the trends of modern ICT solutions used in logistics. These are among others: Sensors, Logistics Internet Platforms, Sharing Economy, Green Energy in Logistics, Omnichannel, Extended Reality, Internet of Things, Robotics and Automation, Big Data Analyses, Cloud Solutions, Drones, “Hyperloop” Transportation, Connected Life,

Artificial Intelligence, 3D Printing, Virtual Reality, Blockchain, Autonomous Vehicles, Next-Generation Wireless, Smart Containerization. On their basis, the study presented in the article was developed.

This paper aims at checking whether manufacturing enterprises are willing to invest in modern ICT solutions for their logistics processes. It is possible to assume that big-sized enterprises can afford such solutions. But what about the micro, small and medium ones? Especially that these have the most significant share of each country's economy. To find out the current trends in Logistics 4.0 of manufacturing enterprises, the poll study was carried out within the micro, small and medium enterprises from Poland and Germany. At the base of the results, some positive conclusions highlight the future of Logistics 4.0. They also contribute to the identified research gap: the lack of evidence regarding the possibilities of applying modern ICT solutions to logistics processes of micro, small and medium manufacturing enterprises to follow the Logistics 4.0 era.

Methodology

This study had a poll character and was conducted to analyze the chances of implementing modern ICT solutions in the logistics of manufacturing enterprises. The study's main objective is to assess the possibility of implementing modern ICT solutions in the logistics of manufacturing enterprises in the context of the concept of Logistics 4.0. The research questions posed here were as follows:

Research question 1: *Which of the ICT solutions are likely to be implemented in logistics in the short term (<5 years) and in the long term (> 5 years)?*

Research question 2: *Which of the ICT solutions that can be implemented in logistics in the short term (<5 years) and in the long term (> 5 years) are preferred by micro, small and medium-sized manufacturing enterprises?*

Research question 3: *Do manufacturing companies see the benefits of the potential implementation in the short term (<5 years) and in the long term (> 5 years) of ICT solutions for logistics in relation to the assessment of the logistics strategy and the assessment of profitability changes?*

The study was conducted in accordance with the following stages of the research process:

1. Based on comprehensive literature studies related to Logistics 4.0 and the possibilities of using ICT solutions in this area, a quantitative survey in the form of a questionnaire was developed. The questionnaire contained 5 main questions (due to the poll nature of the survey), and the final confidential part. A pilot study was carried out on a sample of 10 Polish manufacturing companies to eliminate any ambiguities so that the respondents had no doubts as to whether the questions were unclear.
2. In the second quarter of 2021, the main study was carried out among Polish and German production enterprises using CATI and CAWI methods. The condition for participation in the study was to declare the logistics activities. Participants were also asked not to include the transient turbulence associated with the Covid-19 pandemic in their responses, as this could negatively impact the study's overall results.
3. The adopted research sample was statistically verified as representative of the population of micro, small and medium-sized manufacturing enterprises. 372 manufacturing companies (204 from Poland and 168 from Germany) took part in the study; they were randomly selected according to their size based on the level of employees. The sample structure covered: 54.1% micro, 30.3% small, and 15.6% medium-sized manufacturing enterprises.
4. The results of the study were subjected to quantitative analysis with the use of an Excel spreadsheet and Statistica software. In order to elaborate the results, the methods of descriptive statistics, the distance weighted least squares smoothing method, and Mann-Whitney U statistical significance tests were used.

Research results

The research allowed us to obtain information about the investment intentions of manufacturing enterprises in modern ICT solutions, adjusting their logistics activity to the concept of Logistics 4.0. The representative sample allowed for the analysis of the obtained results with the conclusions extended on the general of manufacturing enterprises. The random selection of a sample provides a minimized image of the entire population and reflects the studied features and variables.

Using the methods of descriptive statistics, the answer to the first research question was obtained – RQ1: *Which of the ICT solutions are likely to be implemented in logistics in the short term (<5 years) and in the long term (> 5 years)?* (Fig. 1).

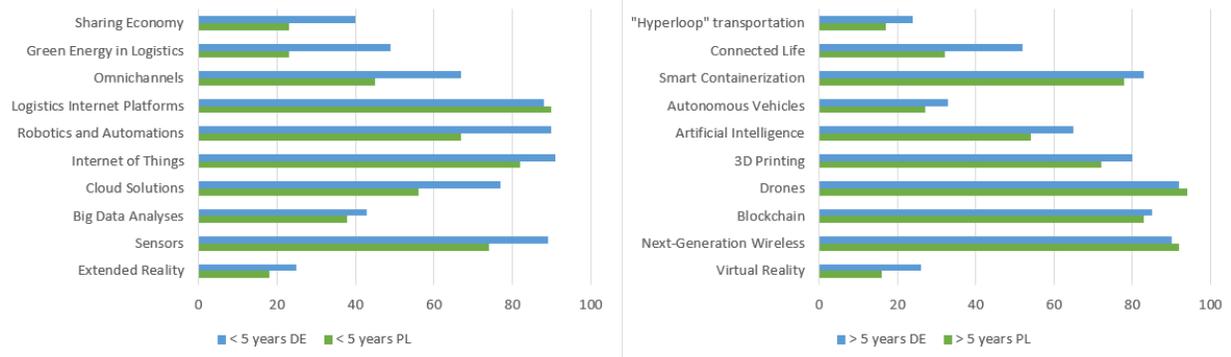


Figure 1. Declared for implementation ICT solutions in logistics of Polish and German manufacturing enterprises in less than 5 years and in the further future.

The question had the possibility of multiple-choice. The respondents were asked to define which ICT solutions can be implemented in their company logistics in the next 5 years and/or in the future (> 5 years). The analysis of the distribution of responses shows that in the area of logistics, manufacturing companies would most often spend their investments shortly (up to 5 years) on ICT solutions in the form of Logistics Internet Platforms, Internet of Things and Sensors, as well as Robotics and Automation. Among these solutions, the least popular are Extended Reality, Sharing Economy, and Green Energy in Logistics. At the same time, respondents choosing advanced ICT solutions to be implemented to support logistics in more than 5 years chose to invest in Drones, Next-Generation Wireless and Blockchain, as well as Smart Containerization. Investments in Virtual Reality, "Hyperloop" Transportation and Autonomous Vehicles were marked the least frequently. Moreover, it is worth noting that German manufacturing enterprises are more willing to invest in all ICT solutions that improve logistics processes. It is evident in the case of solutions planned to be implemented in the shorter term.

To answer the second research question - RQ2: *Which of the ICT solutions that can be implemented in logistics in the short term (<5 years) and in the long term (> 5 years) are preferred by micro, small and medium-sized manufacturing enterprises?* - a non-parametric test of significance of mean differences was used (Mann-Whitney U test). It was used to determine whether the differences in assessing the chances of implementing ICT solutions to logistics are statistically significant between selected groups of manufacturing companies: the tests compared micro and small, micro and medium, small and medium.

Due to the complexity of the calculations, the article presents (Tab. 1) only the test results for the variables that are statistically significant. (1 – Sensors; 2 – Logistics Internet Platforms; 3 – Internet of Things; 4 – Cloud Solutions; 5 – Drones; 6 – 3D Printing; 7 – Next-Generation Wireless; 8 – Smart Containerization).

Table 1. The Mann-Whitney U test values and mean evaluations for 1 to 20 variables of ICT solutions

Variable	Micro/Small		Micro/Medium		Small/Medium		Mean eval. of enterprise		
	Z	p	Z	p	Z	p	Micro	Small	Medium
< 5 years									
1.	4.779	0.012	3.487	0.016	0.047	0.981	3.5	3.1	3.1
2.	0.640	0.533	2.035	0.053	1.405	0.146	3.3	3.2	2.9
3.	0.518	0.622	4.119	0.011	3.059	0.013	3.8	3.7	3.5
4.	3.033	0.013	2.920	0.014	0.389	0.715	3.8	3.6	3.6
> 5 years									

5.	-2.413	0.027	-0.508	0.561	0.632	0.545	3.3	4.4	3.9
6.	2.112	0.046	0.477	0.652	-1.169	0.257	2.4	2.1	2.4
7.	-1.407	0.145	-2.334	0.031	-1.215	0.239	1.3	1.5	1.6
8.	-2.658	0.019	-2.095	0.048	-0.234	0.834	1.2	1.5	1.5

Z – the value of U Mann-Whitney test; p – the value of test probability

It can be concluded that in the area of modern ICT solutions in logistics declared by manufacturing companies as possible to implement shortly (<5 years): the chance of implementing Sensors in the logistics practice in the group of manufacturing micro-enterprises is significantly different - lower - than in small ($Z = 4.779$; $p = 0.012$) and medium-sized enterprises ($Z = 3.487$; $p = 0.016$); at the same time, the implementation of ICT solution in the form of Logistics Internet Platforms in logistics processes in micro-enterprises has significantly greater chances than in medium-sized enterprises ($Z = 2.035$; $p = 0.053$). Internet of Things has a possibility to be implemented in the logistics of medium-sized enterprises significantly more often than in micro ($Z = 4.119$; $p = 0.011$) and small ones ($Z = 3.059$; $p = 0.013$). Logistics investments of micro-enterprises in an ICT solution - Cloud Solutions are declared significantly less frequently than by small ($Z = 3.033$; $p = 0.013$) and medium enterprises ($Z = 2.920$; $p = 0.014$).

In terms of logistics ICT solutions that can be implemented in the long term (> 5 years), it can be indicated that: micro-enterprises will significantly less often invest in Drones to support their logistics than small ones ($Z = -2.413$; $p = 0.027$). In micro-enterprises, 3D Printing is more likely to be implemented than in small enterprises ($Z = 2.112$; $p = 0.046$). Next-Generation Wireless is less likely to be implemented in micro than medium-sized enterprises ($Z = -2.334$; $p = 0.031$). And finally, the potential implementation of Smart Containerization in the logistics of micro-enterprises is significantly smaller than in the logistics of small enterprises ($Z = -2.658$; $p = 0.019$) and medium enterprises (-2.095 0.048).

To answer the last research question – RQ3: *Do manufacturing companies see the benefits of the potential implementation in the near perspective (<5 years) and in the future one (>5 years) of ICT solutions for logistics in relation to the assessment of the logistics strategy and the assessment of profitability changes?* – graphical simulations were carried out using the distance weighted least squares smoothing method (Fig. 2).

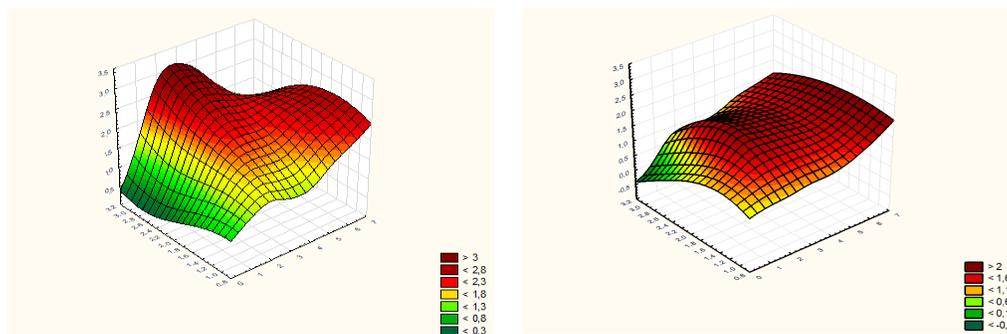


Figure 2. Simulations of the relationships between the potential implementation of ICT solutions to logistics in <5 years (a) and > 5 years (b) and the assessment of the logistics strategy and the assessment of changes in profitability in manufacturing enterprises.

Presented surfaces allow for the general inference about the relationships between the development of selected variables: (a - left Fig. 2) modern ICT solutions in logistics that can be implemented in the perspective of up to 5 years, therefore Sensors, Logistics Internet Platforms, Sharing Economy, Green Energy in Logistics, Omnichannel, Extended Reality, Internet of Things, Robotics and Automation, Big Data Analyzes, Cloud Solutions; and (b - right Fig. 2) ICT solutions in logistics that can be implemented in the perspective of more than 5 years, therefore Drones, "Hyperloop" Transportation, Connected Life, Artificial Intelligence, 3D Printing, Virtual Reality, Blockchain, Autonomous Vehicles, Next-Generation Wireless, Smart Containerization versus changes to other variables - the assessment of the logistics strategy in the surveyed manufacturing companies and their assessment of changes in profitability.

The interpretation of the relations simulation (Fig. 2 a) shows that with the increase in the assessment of the importance of logistics strategy in the activities of manufacturing enterprises, as well as with the increase in the assessment of profitability changes related to logistics activities, the possible chance of implementation in these enterprises shortly (< 5 years) of modern ICT solutions supporting logistics also increase. At the same time, for enterprises with a generally high assessment of the importance of a logistics strategy, the chance of such an implementation is slighter in terms of impact.

The assessment of changes in the profitability of logistics activities is crucial. If this rating is low, it has a positive impact on implementing ICT solutions in the company's logistics. However, if it is high and the logistics strategy's assessment is low, it has a negative impact on the potential investments of manufacturing enterprises in ICT solutions for logistics. On the other hand, the simulation of relations (Fig. 2 b) shows that with the growing importance of the logistics strategy in manufacturing companies, regardless of the assessment of profitability changes of logistics activities, the possible chance of these companies to implement modern ICT solutions in the future (> 5 years) increase.

Conclusion

The presented results highlight the willingness of manufacturing enterprises to implement modern ICT solutions for logistics. They notice the potential of such possibilities as the essential support of logistics activity. As we approach the next fifth industrial revolution, using ICT solutions in logistics becomes a necessity. So, the poll survey allowed us to determine the future directions of further in-depth research. Our research plan assumed a preliminary assessment of the possibilities in the area under investigation. Having confirmed our initial assumptions, we intend to conduct a complete analysis of the literature in the area of each ICT solution and the possibility of its use in logistics. On this basis, a questionnaire will be developed, which will be further supplemented with interviews. The research sample will also be expanded, purposefully and layered for better representativeness of the obtained results. Such prepared research should result in obtaining a measurably complete picture of the use of ICT solutions in logistics 4.0 of production companies. The study will take into account the cross-sectional areas of activity of these enterprises - organizational, strategic, functional, managerial, technical, technological and financial. Such implementation of the research will enrich the literature with a comprehensive thematic study and a series of research articles. In addition, it will indicate the opportunities and possibilities of using ICT in economic practice, including on the basis of good practices resulting from the research. Of course, the assumed plan takes into account the modifications resulting from the variability of many research and organizational parameters, so it should not be treated as its final form.

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