

DIGITAL TRANSFORMATION OF LOGISTICS: HOW MODERN TECHNOLOGIES INCREASE SUPPLY CHAIN SAFETY

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Abstract: This paper is focused on the analysis of key technologies that contribute to increasing the safety of the supply chains in logistics. This topic was taken up by the author due to the development of technologies such as the Internet of Things, artificial intelligence, blockchain or Big Data, this topic allows for their practical application in the context of logistics. It also highlights potential challenges associated with implementing new technologies and their importance in building more resilient and flexible supply chains in the future. The aim of the paper is elaboration of recommendations for enterprises for supply chain safety improvement related to digital transformation of logistics issues. Authors has made literature review that allows for collecting and synthesizing current research and publications on digital transformation in logistics and impact of modern technologies on supply chain safety.

Keywords: digital transformation, logistics, management, supply chain, safety

1. INTRODUCTION

Supply chain safety is one of the biggest challenges of modern logistics. In the era of globalization and increasingly complex supply networks, threats such as cyberattacks, theft or damage to goods pose a serious risk to companies. Digital transformation in the logistics industry provides effective tools to combat these threats, thanks to the implementation of advanced technologies (Kot, 2020). To better understand how modern technologies affect supply chain security, it is necessary to take a closer look at the concept of digital transformation itself. It is a process where digital technologies are used to improve efficiency, organizational capabilities and business results (Poszytek, et al., 2024). Digital transformation is revolutionizing many areas, and one of them is logistics, which is one of the most dynamically developing areas. Logistics is a process in which the flow of goods and services from producer to consumer is managed, modern technologies are most widely used there and cause that traditional methods of the supply chain management are replaced with more efficient and flexible solutions (Armengaud, 2017). While the state of digitalization for traditional industry players is overall on a low to medium level, an increasing number of companies understood the impact that the digital transformation will have on them and intend to follow the call of the times, ready to overcome barriers such as high costs, lack of standards, and unclear benefits. Companies



that do not proactively adapt their digital strategy will not only be left behind but also vanish faster and more surprisingly than this was the case in the past (Kern, 2021).

Logistics is a key element of the supply chain, which includes facilitating the organization in relations with suppliers and customers in various processes and activities that create value in the form of products and services delivered to final consumers (Kowalak, 2010). For the supply chain to be effective, a systems approach must be taken what means that companies must understand the interdependencies of decision-making regarding key areas of activity both within the organization and between them (Janczewski, 2018). The most important aspect of the supply chain is its security during transport and at the place where transshipment takes place, because in these sectors goods are more exposed to risk. The risks that goods are most exposed to include theft, damage, natural disasters, and cyberattacks that may disrupt the smooth operation of the chain (Jażdżewska-Gutta, 2013).

Today's supply chains have become increasingly complex and geographically distributed. In order to maintain security, companies must have tools that allow them to quickly respond to changing conditions and identify potential threats. The use of tools such as IoT (Internet of Things), AI, blockchain, and big data offer a number of possibilities aimed at improving the safety of supply chains (Maternowska, 2019, Alesiuniene, 2021, Kern, 2021).

IoT (Internet of Things) is a technology that enables automatic data exchange along with real-time process monitoring. Thanks to this, companies can optimize supply chains while increasing the efficiency of managing their resources (Ostrowski 2024). AI (Artificial Intelligence) is used in many ways to increase the efficiency of the supply chain. For example, artificial intelligence can be used to optimize routes, manage inventory, and forecast demand. This application is expensive due to its implementation and the need to train employees (Zieliński, et al. 2023).

Supply chain management, and logistics in particular, is a lucrative application area for the Internet of Things (IoT), which can offer opportunities to improve the efficiency of material flows. The development of logistics often aims to reduce transport costs, speed up operations, and improve the security of supply and the transparency of supply chains that are often global (Helo, 2024).

Blockchain is used to improve the efficiency, transparency, and security of supply chains. It offers assistance in reducing costs and improving cooperation between stakeholders. This technology is used, for example, in tracking the movement of goods and materials in the supply chain, which helps to ensure that they are delivered to the right place at the right time. It can also be used to verify the authenticity of a product, helping to prevent counterfeiting and fraud (Brzeziński, 2020).

Big Data can be used to optimize the overall business and its core operations. Broad logistics operations and activities, encompassing multiple markets or units, require efficient information flow and appropriate selection and combination of information to ensure compliance with the 7W principles. In addition, forecasting and analytics enable better resource utilization and greater efficiency. It also optimizes basic issues such as logistics, i.e. resource utilization and allocation, shortening lead times, and waste disposal and return (Nowik, 2018). In summary, the Internet of Things, artificial intelligence, blockchain, and big data are playing an increasingly important role in the modern supply chain. Each of these technologies offers unique opportunities to optimize processes, increase transparency, and improve safety.

2. RESEARCH OBJECT AND METHODOLOGY

The object of the research was conducted in period 2022 – 2023 and it was done in the form of questionnaire based on digital maturity level analysis in selected enterprises. Analyzed group of 100 enterprises represented sectors: logistics, manufacturing and transport services in Poland. Research sample was selected because of the criteria related to implementing and planning to implement digital technologies in the area of supply chain management. It was examined to what extent various companies use digital technologies and how it affects their activities. In particular, the study focuses on the use of IoT, AI, blockchain and Big Data.

The aim of the research was to identify the degree of adaptation of selected technologies, the benefits of its implementation, as well as the main barriers and challenges in their implementation. The study was conducted by using an online survey among a wide range of specialists from various areas of business activity, including managers, logisticians, IT specialists and supply chain managers. The study includes a detailed analysis of the current state of digitalization in companies operating on the Polish market, with particular emphasis on technologies used in logistics and supply chain management. The questions concerned both the level of implementation of individual technological solutions and their impact on the operational efficiency, supply chain efficiency and safety issues. Additionally, the survey also includes questions related to obstacles to the implementation of new technologies and the prospects for digital development in the near future.

3. RESEARCH RESULTS AND DISCUSSION

The online survey questionnaire contains questions related to characteristic of the enterprise and its level of digital maturity on digital technologies implementation in the area of supply chain management. The responses were submitted by companies that varied in terms of employment size and industry they specialized in. The first part of the survey concerns characteristics of the analyzed enterprises, what was presented in figure 1.

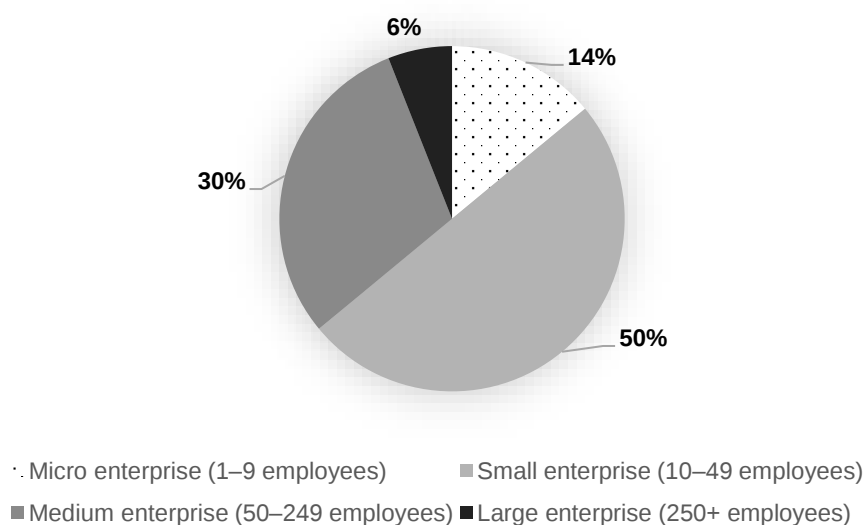


Fig. 1. Types of analyzed enterprises

The largest group that decided to participate in the survey are small enterprises employing 10-49 employees, constituting 50% of the entire research sample. The second group

include medium-sized enterprises employing 50-249 employees (30%). Figure 1 shows the presence of many small and medium-sized enterprises, that create an important economic segment. The smaller share of enterprises with a large number of employees may suggest that the market is dominated by a few large corporations with a significant market position. Respondents were asked about the type of business activity of the enterprise (Figure 2).

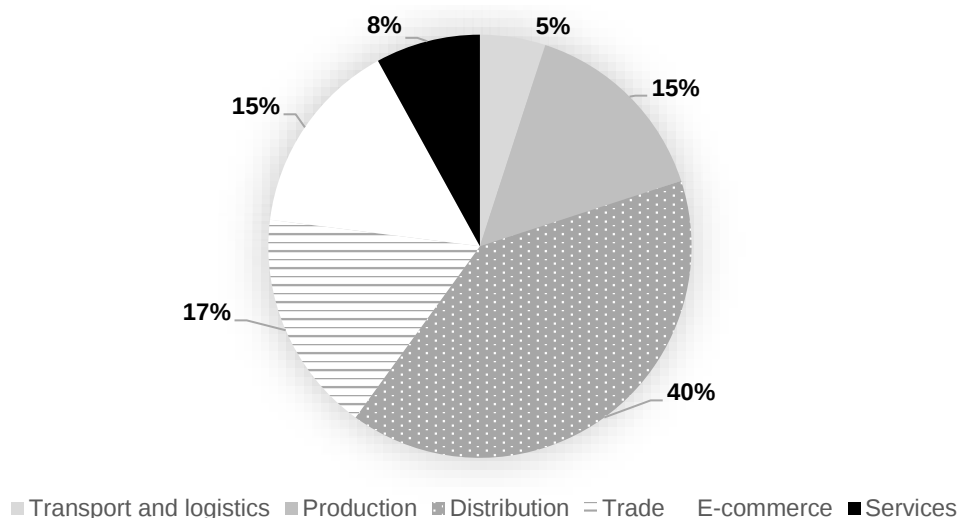


Fig. 2. Profile of the analyzed enterprise activity

Figure 2 illustrates the structure of companies activities in the analyzed group. Companies operating in the distribution sector constitute the largest share, amounting to 40%. The service sector is in second place, with a share of 17%. The transport, logistics and production sectors have a similar share of 15% respectively. Trade has an 8% share, while e-commerce has the smallest share (5%). There is a noticeable diversity among the surveyed group of companies in terms of the activities they conduct, with companies from the distribution sector clearly dominating. The services, transport and logistics and production sectors present a similar percentage share in the analyzed group. Figure 3 shows the job position held by the respondents.

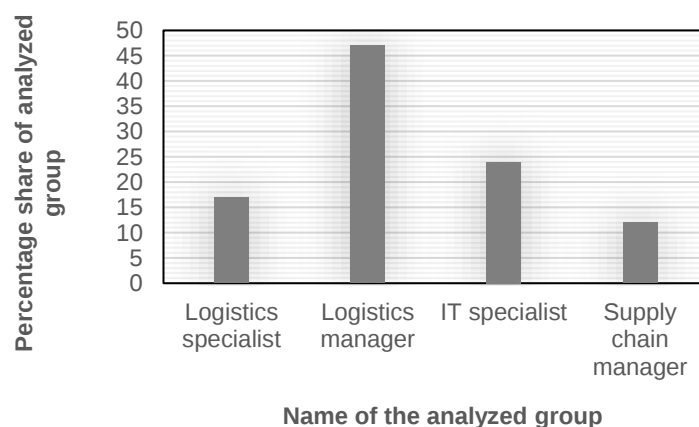


Fig. 3. The structure of the respondents work position

The vast majority of respondents (47%) are logistics managers. Logistics specialists (24%) are in second place. IT specialists make up 17% of the surveyed group, and supply chain managers 12%. In connection with these results, it can be concluded that the analyzed group is mainly composed of entities directly related to the logistics sector, both at the operational and managerial level. Considering that the majority of the surveyed people are specialists from the logistics industry, it is important to analyze whether enterprises work for have implemented or plan to implement digital technologies in this area (Figure 4).

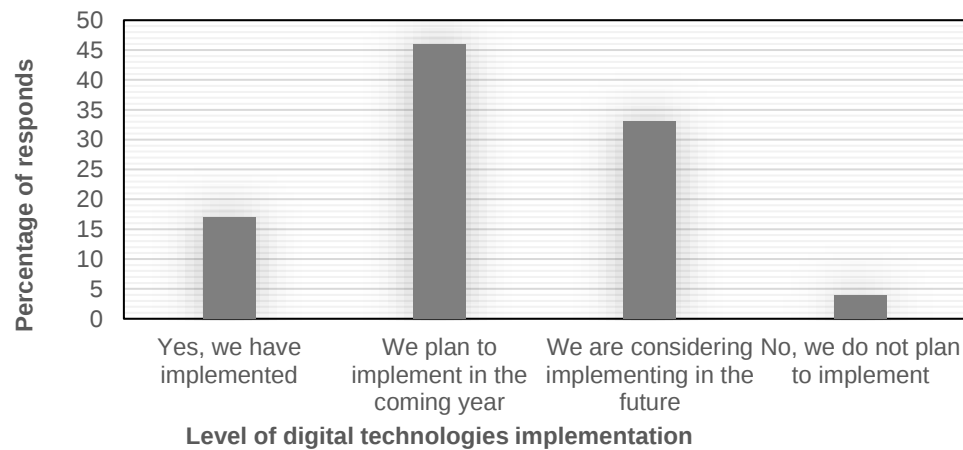


Fig. 4. Implementation of digital technologies in Logistics

Figure 4 presents results of the study on the implementation of digital technologies in the area of logistics. As many as 46% of the surveyed companies have already implemented such solutions. Another 33% plan to implement digital technologies in the coming year, which indicates a great interest in this topic. Nearly 17% of companies are considering implementing such solutions in the future. The smallest percentage (4%) are companies that do not plan to implement digital technologies in logistics. The results of the study indicate a clear digitization trend in the logistics processes in the analyzed group of companies. Considering that most companies have already implemented or plan to implement digital technologies, it is worth taking a closer look at which specific solutions are most often chosen. Figure 5 presents a summary of the most frequently implemented digital technologies in the area of logistics.

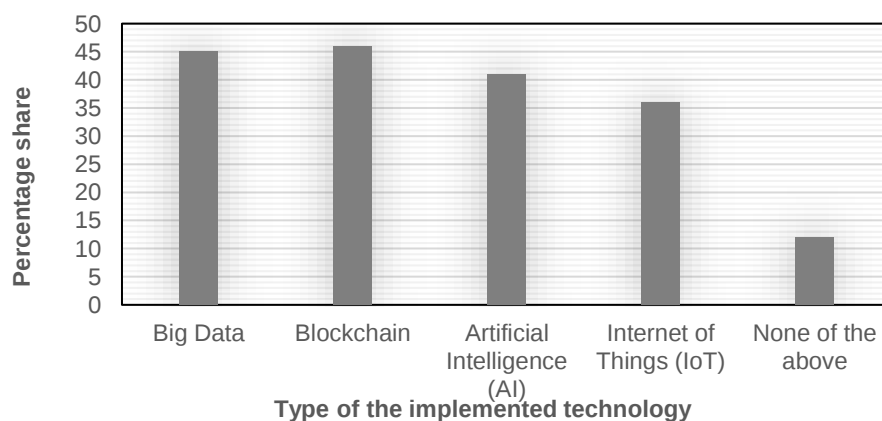


Fig. 5. Technologies implemented in enterprises

Figure 5 shows the prevalence of various digital technologies implemented in enterprises. The most commonly used technology is blockchain, which has been implemented in 46% of the surveyed companies. In second place are solutions based on Big Data, which are used by 45% of enterprises. Artificial intelligence has been used in 41% of companies, and the Internet of Things in 36%. Only 12% of the surveyed enterprises have not implemented any of the mentioned technologies. It can be seen that digital technologies such as blockchain and big data are very popular in enterprises, which shows the growing importance of digitization in enterprises. Since Big Data is one of the most commonly implemented technologies, it is worth taking a closer look at how companies assess its impact on supply chain security. The figure below presents the results of a study assessing the impact of Big Data technology on supply chain safety.

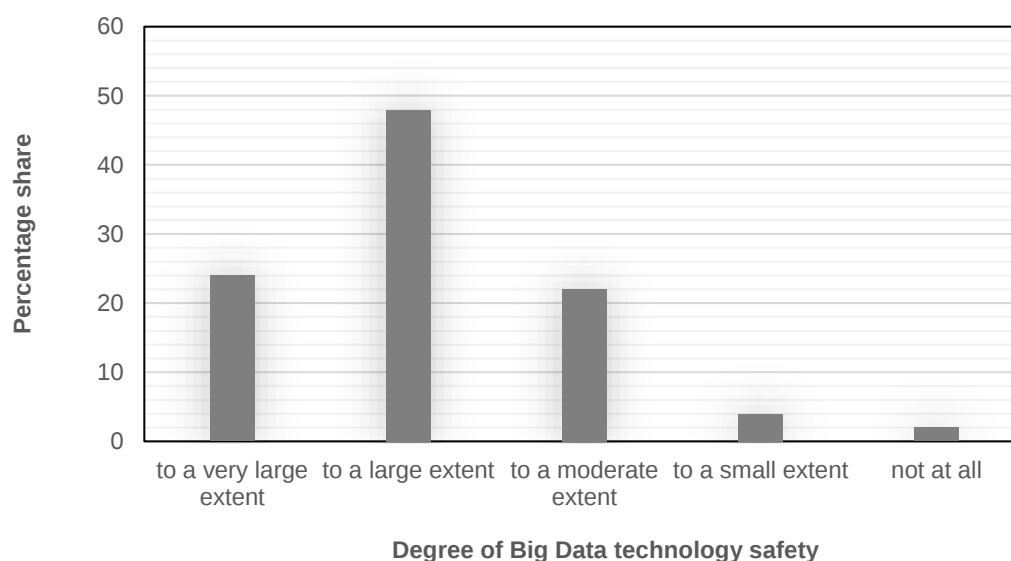


Fig. 6. Safety level in the Big Data technology application in the supply chain

Figure 6 presents an evaluation of the impact of Big Data technology on the supply chain safety. As many as 48% of respondents believe that Big Data significantly improves supply chain security. Another 24% of respondents assess this impact as high. In turn, 22% of respondents believe that the impact is moderate. Only 4% of respondents assessed the impact of Big Data on supply chain security as low, and 2% respondents assess it as not at all important. Therefore, it can be stated that the majority of respondents positively assess the impact of Big Data technology on supply chain security. Since Big Data is perceived as a significant factor improving supply chain security, it is worth taking a look at another technology that also has great potential in this area - blockchain. Figure 7 presents evaluation of the blockchain on the transparency and traceability of goods in the supply chain.

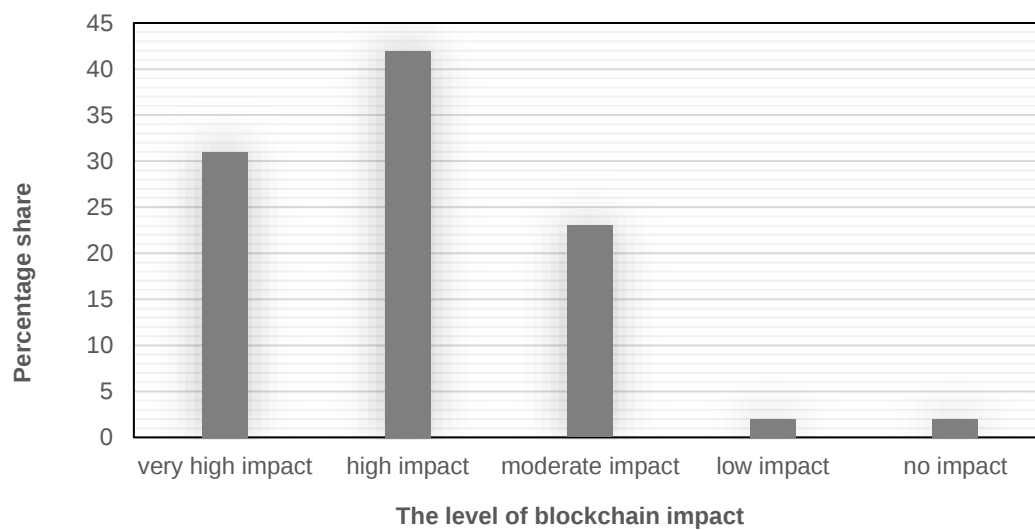


Fig. 7. The impact of blockchain on the transparency and traceability of goods in the supply chain

The survey results show that respondents positively assess the impact of blockchain technology on the transparency and traceability of goods in the supply chain. As many as 42% of respondents believe that this impact is very large, and another 31% of respondents evaluate it as a large one. Only 23% of respondents indicated a moderate impact of blockchain, while 3% and 1% of respondents noted a small or no impact, respectively. It can therefore be concluded that blockchain is perceived as a technology that significantly improves the transparency and tracking of products in the supply chain. Since blockchain is assessed so positively, it is worth taking a look at another technology that also has great potential in the automation of logistics processes - artificial intelligence. Figure 8 presents the results of the survey regarding the assessment of the impact of solutions based on artificial intelligence on the automation of logistics processes.

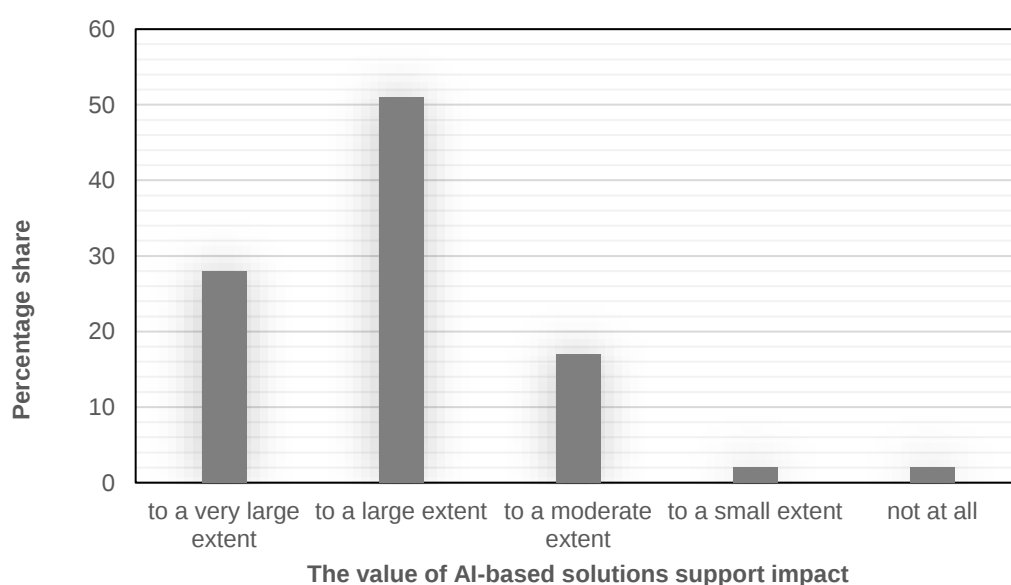


Fig. 8. The value of the impact of AI-based solutions on the logistics processes automation

The survey results show that respondents highly value the impact of AI-based solutions on the logistics processes automation. As many as 51% of respondents believe that this impact is very large, and another 28% rate it as large. Only 17% of respondents indicated a moderate impact of AI, while 3% and 1% of respondents noted a small or no impact, respectively. It can therefore be stated that AI is perceived as a key technology supporting automation in logistics. Considering the significant impact of AI on automation, it is worth paying attention to another technology that is also playing an increasingly important role in logistics - the Internet of Things (IoT).

Results of the survey related to the assessment of the most important benefits of implementing IoT in enterprises show that the most important benefits of implementing IoT in the logistics industry are: reducing operating costs (45%), improving transport efficiency (42%) and early detection of threats (38%). The next places were taken by monitoring transport conditions (34%), improving communication between systems (34%) and better fleet management (31%). Optimization of warehouse processes turned out to be the least important (25%). Moving on, it is worth taking a look at the main barriers that, according to respondents, pose the greatest challenge to implementing digital technologies in logistics.

The analysis shows that the biggest challenges in implementing digital technologies in logistics are problems with integration with existing systems (44%) and high implementation costs (41%). Other barriers include long implementation and return on investment times (35%) and lack of qualified staff (33%). Concerns about data security (28%) and low level of understanding of the benefits of digital technologies (24%) are also significant, although to a lesser extent. The smallest obstacle turned out to be organizational resistance to change (11%). Moving on, it is worth taking a look at whether respondents believe that the use of Big Data could support the forecasting of risks in the supply chain.

The survey results show that the majority of respondents (definitely yes – 36%, rather yes - 53%) believe that the use of Big Data can help predict risks in the supply chain. Only 11% of respondents find it difficult to determine what potential lies in this technology. This means that companies are aware of the possibilities offered by Big Data in identifying potential threats and are proactively responding to them.

The broader perspective on the impact of new technologies on supply chain safety was the next stage of the survey. Results of the research results analysis show that respondents mostly positively assess the impact of new technologies on improving safety in the supply chains. As many as 39% of respondents believe that this impact is very high, and another 36% assess it as high. Only a small proportion of respondents (22%) indicated a moderate impact of new technologies, while 3% noted a small impact. It can therefore be concluded that new technologies are perceived as a significant factor in increasing safety in the supply chains. Considering the positive opinions on the impact of new technologies on security, it is worth taking a broader look at the digital transformation in the logistics. Majority of enterprise are implementing new technological solutions to increase their competitiveness and efficiency. The general attitude of companies towards the digital transformation of logistics is positive – 47% of respondents indicate a gradual implementation of new technologies, and 28% strive for their full implementation. Only 3% of companies remain skeptical, which indicates a great openness of the industry to digitalization, although with varying pace of its implementation.

4. CONCLUSION

In summary of the conducted research analysis, it is stated that the collected data is proof that companies are implementing technologies in their companies that can improve their functionality. The implementation of new possibilities guarantees them a high place in the competitive market, where quality and time are the most important factor for customers. The presented research results provide interesting observations on the attitudes of companies towards digital transformation in logistics, with particular emphasis on the role of new technologies in improving the security of supply chains and the use of Big Data to forecast risks. The majority of respondents (over 75%) assess the impact of new technologies on improving security in supply chains very positively or positively. This indicates a growing belief that investments in technological solutions are necessary to ensure business continuity and minimize risk. Respondents recognize the great potential of Big Data in forecasting risks in supply chains. Over 60% of respondents believe that the analysis of large data sets can significantly contribute to identifying potential threats and proactively responding to them. Although most companies are open to new technologies, there is a significant difference in the degree of advancement of implementation. Almost half of the respondents take a neutral position, implementing new technologies cautiously. On the other hand, every fifth company is actively pursuing the full digitalization of its logistics processes. The neutral and negative positions of some respondents indicate the need for further education and building awareness about the benefits of digital transformation.

Although most companies are open to new technologies, there is a significant difference in the level of advancement of implementation. Almost half of respondents take a neutral position, implementing new technologies cautiously. On the other hand, every fifth company is actively pursuing full digitalization of its logistics processes. The neutral and negative positions of some respondents indicate the need for further education and building awareness of the benefits of digital transformation. Companies need support in selecting the right technologies, implementing them and integrating them into existing systems. Trends indicate that the digitalization of logistics will continue at an increasingly rapid pace. Companies that do not take appropriate measures may lose their competitiveness. Investments in new technologies such as artificial intelligence, big data or IoT are essential to improve the efficiency, flexibility and security of supply chains. Digital transformation should be treated as a process covering the entire organization. It is necessary to engage all employees, from management to operational staff. Collaboration with technology providers, business partners and other entities operating in the supply chain is key to achieving a successful digital transformation. To be able to effectively implement digital transformation in logistics, companies should enable their employees to participate in training and educational programs on new technologies to be able to smoothly implement and use new tools. Training can start with pilot projects and gradually expand the scope of the transformation, which allows to minimize risks and manage changes more effectively. It is necessary to create a working environment that is conducive to creativity and openness to new ideas. Supporting employee initiatives and providing adequate resources are key to success. It is also necessary to build strong relationships with technology suppliers and business partners, which bring benefits such as access to the latest solutions and access to expert knowledge. Regular assessment of implementation progress and analysis of effects allows for the identification of areas requiring improvement and process optimization.

The presented conclusions and recommendations are a starting point for further discussions and actions. The digital transformation of logistics is a complex process that requires continuous improvement and adaptation to changing market conditions.

Enhancing supply chain safety through digital transformation is a critical focus for enterprises aiming to improve efficiency and resilience.

Key recommendations for enterprises to improve supply chain safety through the digital transformation of logistics are following:

1. Implement Advanced Monitoring and Tracking Systems:

- adopt IoT Sensors: Use Internet of Things (IoT) devices for real-time tracking of goods, monitoring environmental conditions (e.g., temperature, humidity), and ensuring cargo safety,
- leverage GPS and Telematics: Enable real-time tracking of shipments and vehicles to enhance visibility and prevent theft or loss,
- digital Twin Technology: Simulate supply chain operations to predict and mitigate risks before they occur.

2. Enhance Data Security:

- secure Communication Channels: Use encryption and secure communication protocols for data exchange between supply chain partners,
- regular Cybersecurity Audits: Identify vulnerabilities in logistics systems and implement solutions to protect against cyber threats,
- adopt Blockchain Technology: Ensure transparency and tamper-proof documentation of transactions and shipping details.

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4. Automate Processes for Accuracy and Efficiency:

- implement Robotic Process Automation (RPA): Automate repetitive tasks like data entry, invoicing, and order processing to minimize human errors,
- use Autonomous Vehicles and Drones: Explore the use of automated vehicles and drones for safer and faster last-mile delivery,

5. Strengthen Collaboration and Integration:

- cloud-Based Platforms: Use cloud technology to create a centralized hub for communication and data sharing among supply chain stakeholders,
- integrated Supply Chain Solutions: Adopt platforms that integrate inventory management, order processing, and logistics tracking for end-to-end visibility,
- collaborative Planning Tools: Enable partners to co-create plans, share forecasts, and reduce disruptions.

6. Train Employees on Digital Tools:

- upskilling Programs: Provide training on emerging technologies like IoT, AI, and blockchain for logistics and supply chain teams,
- foster a Digital-First Culture: Encourage employees to embrace and adapt to digital transformation initiatives.

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