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DIGITIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Svitlana Smerichevska, Larysa Prodanova, Oleksandr Yakushev. "Digitization of logistics and supply chain management". The article presents theoretical and applied aspects of digitalization of logistics and supply chain management. It is emphasized that the processes of digitalization of supply chains and logistics are a modern requirement for increasing business efficiency, as well as solving environmental, social and management problems of successful companies. Digitization of supply chains and logistics is defined as the integration of digital technologies and the implementation of digital tools to optimize, automate and increase the efficiency of all stages of the logistics process. Key modern technologies in logistics and supply chains are examined, including artificial intelligence (AI), the Internet of Things (IoT) and Big Data. The role of AI in optimizing logistics processes, forecasting market behavior, inventory management and route planning is outlined. Emphasis is placed on the importance of IoT for tracking goods, monitoring storage conditions and vehicle maintenance. The role of Big Data in optimizing supply chains, improving decision-making and compliance with regulatory requirements is analyzed. The use of digital documentation and electronic document circulation are highlighted as important areas of digitization. The difference between digitization of documents and digitalization of document circulation is revealed: digitization, or digital preservation, refers to

the transfer of information from paper documents to electronic format for convenient and safe storage of files and access to them in the future; digitalization involves the creation of documentation in computer applications, its intelligent processing and analysis, its accumulation in digital repositories, and the wide use of its data to solve various problems. It is noted that one of the main directions of digitization of documents is the automated reading of documents and data entry, which is implemented using specialized software for automatically extracting information from paper documents and entering it into digital systems. The list of the main logistics documents that are subject to digitization and the digitization of which leads to an increase in the efficiency of the supply chain (delivery confirmation, bill of lading, packing lists, invoices, cargo manifest, etc.) is provided. It was concluded that digitalization of logistics is a significant factor for modern companies seeking to increase their competitiveness in the market. It also enables the integration of all company divisions, improves product tracking, speeds up customs procedures, optimizes transport costs and increases the flexibility of return management. Despite the shortcomings that accompany this process, digitalization of logistics is necessary to achieve sustainable development and effective management of supply chains in today's world.

Keywords: digitalization, Logistics 4.0, logistics, supply chains, logistics documents, digital technologies.

Світлана Смерічевська, Лариса Проданова, Олександр Якушев. «Цифровізація логістики та управління ланцюгами постачання». У статті представлені теоретичні та прикладні аспекти цифровізації логістики, який передбачає впровадження цифрових рішень на всіх етапах логістичного циклу для моніторингу та управління процесами в усьому ланцюжку постачання. Акцентовано, що процеси цифровізації ланцюгів постачання і логістики є сучасною вимогою підвищення ефективності бізнесу, а також вирішення екологічних, соціальних та управлінських проблем успішних компаній. Попри переваги, цифровізація стикається з низкою викликів, які потрібно подолати для її успішного впровадження. Цифровізація ланцюгів постачання і логістики визначена як інтеграція цифрових технологій та впровадження цифрових інструментів для оптимізації, автоматизації та підвищення ефективності всіх етапів логістичного процесу. Розглядаються ключові сучасні технології, що використовуються в цифровій трансформації логістики, зокрема штучний інтелект (AI), Інтернет речей (IoT) та аналіз великих даних (Big Data). Обґрунтовано, що такі технології забезпечують підвищення інформаційної взаємодії, ефективність управління запасами, оперативність інформаційного забезпечення та точність процесів. Зазначено, що впровадження цифрових технологій стикається з такими труднощами як недостатність кваліфікованої робочої сили та доступність даних. Як важливі напрямки цифровізації виокремлено: застосування цифрової документації та електронний документообіг. Розкрито різницю між оцифруванням документів і цифровізацією документообігу. Зазначено, що одним із основних напрямків цифровізації є автоматизоване читання документів і введення даних, які реалізуються із застосуванням спеціалізованого програмного забезпечення для автоматичного вилучення інформації з паперових документів і введення її в цифрові системи. Наведено перелік основних логістичних документів, які підлягають цифровізації, оцифрування яких зумовлює підвищення ефективності ланцюжка постачання (підтвердження доставки, коносамент, пакувальні листи, рахунки-фактури, вантажний маніфест та ін.). Зроблено висновок, що цифровізація логістики: є вагомим чинником для сучасних компаній, які прагнуть підвищити свою конкурентоспроможність на ринку; попри недоліки, цей процес є необхідним для досягнення сталого розвитку та ефективного управління ланцюгами постачань у сучасному світі.

Ключові слова: цифровізація, Logistics 4.0, логістика, ланцюги постачання, логістичні документи, цифрові технології

Introduction. The digitalization of logistics involves implementing digital solutions at all stages of the logistics cycle for monitoring and managing processes

throughout the supply chain, from the receipt of raw materials to the final delivery of the product. Digital transformation in the logistics sector requires increased investment in

modern tools, systems, and technologies to optimize resources, ensuring efficiency. To achieve successful digitalization of logistics in a company, it is necessary to promote the quality use of new technologies. Although this is a necessary and beneficial process, in practice, the digitalization of logistics may face a number of obstacles and problems that need to be overcome for its successful implementation in companies.

Analysis of recent research and publications. The methodology, concepts, optimization models, and strategies for logistics and supply chain management based on the implementation of digital technologies have been formulated and revealed in many foreign and domestic scientific works. In particular, authors O. A. Pokhylchenko [17], B. Bigliardi et al. [2], Yu. O. Shkrygun [22], N. V. Trushkina and K. Yu. Kitrish [21] argue that with the development of the Industry 4.0 concept, the Logistics 4.0 concept emerged, which scientists define as management using advanced technologies of flows of raw materials, semi-finished products, and finished products to meet customer needs. The spread of digital technologies in the industrial sector inevitably has consequences for logistics as well [2]. Based on these, as noted by S. Schrauf and Ph. Berttram [6], new business models are created that integrate every link in the company's value chain: digital workplace, product development and innovation, design and production, distribution, digital sales channels, and customer relationship management. Research has shown that Industry 4.0 will have the greatest impact on the areas of order fulfillment and transport logistics [19]. The supply chain concept developed in the article by M. V. Boychenko [14] is most fully realized in the Logistics 4.0 system.

S. Hrytsenko explores the possibilities of applying digital technologies at the local level in the formation of transport and logistics clusters. The author notes that the implementation of intelligent transport systems, which represent a combination of

modern technologies, transport infrastructure, facilities, and users, will provide a higher level of mobility, safety, environmental friendliness, and economic efficiency of transport services [15, p. 350].

Based on the analysis of specific technologies such as artificial intelligence, Internet of Things, and blockchain, J. D. Torres Leandro emphasizes the advantages of focusing on their use in supply chain management, namely: improving information interaction between subjects influencing supply chains; efficiency of inventory management and its reduction; operational information support in making management decisions; ensuring accuracy of processes and location of goods, which improves management and customer service [9].

Given the presence of a wide range of theoretical developments, it is worth focusing on specific practical aspects of digitalization in logistics and supply chain management.

Formulation of the article's objectives. The purpose of this article is to analyze the current state and practices of implementing digitalization in logistics and supply chain management.

Presentation of the main material. The use of digital technologies in supply chains is a requirement of our time. Along with increasing economic efficiency, digitalization allows overcoming environmental, social, and governance (ESG) issues. As research by the international audit and consulting firm PwC shows, hundreds of surveyed executives and company leaders in the US recognize the benefits of digital transformation in supply chains. Among these companies, 62% have invested in cloud technologies and artificial intelligence, including 55% in machine learning technology. The main areas of activity in which these technologies are used are quality control, operational visibility, and analytical work [5].

As the digitalization of supply chains is a revolutionary transformation with a lack of theoretical achievements and practical experience, it is accompanied by many challenges. Thus, up to 70% of company

executives admit that their investments in operational technologies have not yielded the expected results. Most companies focus more on basic, immediate priorities and problems in their supply chains and less on actions and investments that can help transform supply chains and create long-term value. Despite the large number and potential of technologies, few executives say their companies are using or planning to use them to automate and improve the execution of various supply chain elements in at least the next 2 years. Only about a third of executives say that increasing resilience is the main goal of investing in supply chain technologies. Regarding risk, 86% of respondents agree that their company should invest more in technologies to detect, track, and measure supply chain risk. More than two-thirds of respondents expect that digitalization of their supply chain will require upskilling of employees. Respondents note a reduction in the supply of skilled labor, so they are willing to work with their own staff, including retraining employees for other jobs as their current roles will no longer be needed. Additionally, companies plan to reduce dependence on outsourcing. Lack of digital skills among employees (80%) and availability of data and digital tools (73%) were the most frequently mentioned challenges for integrating ESG into the company's supply chains [12].

The digitalization of logistics provides advantages that optimize the supply chain operation and increase efficiency in all areas of the company's activities. It allows integration with other departments of the company, facilitating coordination of activities and decision-making. Product tracking is improved, making it possible to determine their location and condition in detail at any time. Digitalization also accelerates customs procedures, simplifying bureaucratic processes and reducing waiting times. Additionally, it facilitates order picking and cross-docking, optimizes order preparation, and direct delivery to the end-user. Another important advantage is the

simplification of transportation planning through software specialized in route organization, the implementation of which leads to resource optimization and reduction of transportation-related costs. Reverse logistics, i.e., delivery and returns, becomes more flexible thanks to digitalization. This facilitates returns management and simplifies the processes of refunds or product replacement. The digitalization of logistics also improves demand forecasts, allowing for the adaptation of production and supply according to market needs.

The digitalization of supply chains and logistics means the integration of digital technologies into all their aspects, from automating storage and distribution processes to using advanced software for inventory management and route planning. Logistics management technologies are important tools for ensuring supply chain resilience and effectively responding to future disruption risks, aimed at increasing efficiency, reducing costs, and improving decision-making processes throughout the supply chain, thus contributing to more flexible, accurate, and market-adapted logistics [8; 20].

Let's characterize some modern technologies in logistics and supply chains.

Artificial Intelligence (AI) is a revolution in the logistics sector, enabling it to achieve ultra-high efficiency in process optimization and customer satisfaction, ensuring long-term stability of digital business. Through the application of AI, companies are transforming their procedures into proactive schemes. Operators can predict market behavior and allocate resources appropriately, leading to increased productivity and reduced costs. The successes in implementing artificial intelligence in logistics are due, in particular, to increased market competition. To remain competitive while optimizing operations in supply chains, logistics companies are forced to invest in technologies [6]. Figure 1 shows the level of artificial intelligence implementation in supply chains and manufacturing businesses, which is

determined by the corresponding shares of respondents' answers..

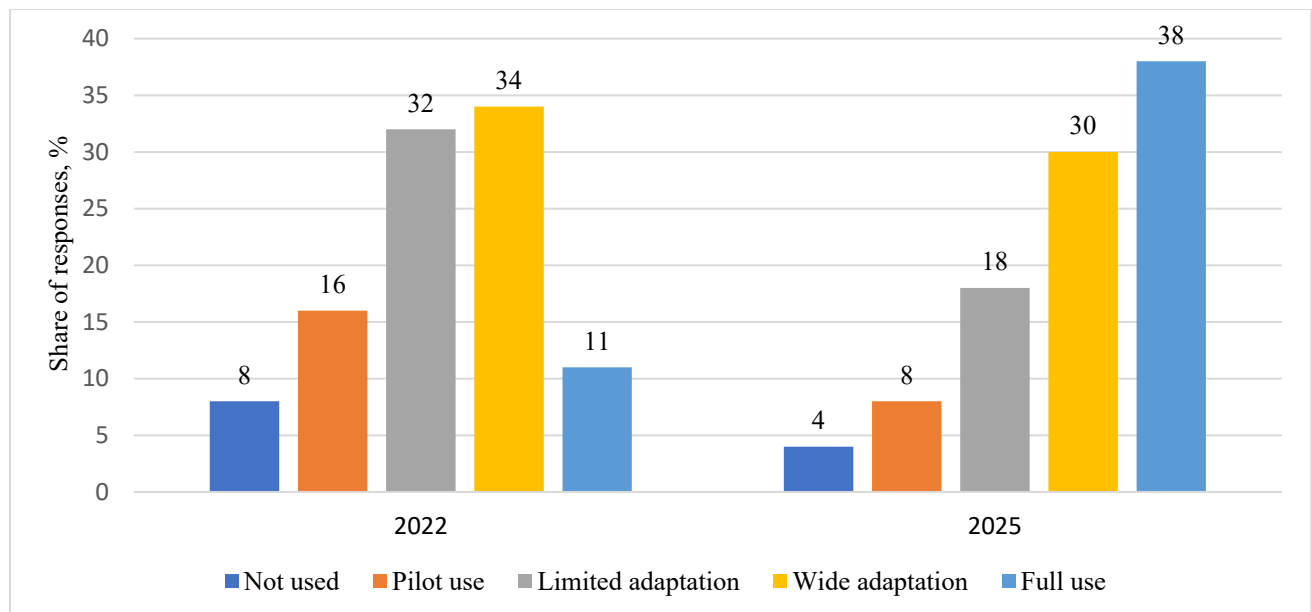


Figure 1 – Level of adoption of AI in supply chains and manufacturing in the world in 2022 and 2025 (forecast)

Source: developed by the authors from [2]

From Figure 1, we can see that in 2022, one-third of executives were preparing for wide and full-scale implementation of AI. It is expected that by 2025, the level of full-scale AI implementation will increase to almost 38%.

AI is used in warehousing, inventory, order preparation, and transportation processes. In inventory control, the application of resource planning software with integrated artificial intelligence and robots allows for efficient inventory management and optimization of storage space. Products are placed according to their arrival, and locations are chosen based on their expected rotation, maximizing the use of available resources.

Thanks to data-based machine learning, artificial intelligence can predict future

customer orders and adjust inventory accordingly. Mass analysis of internet browsing and online purchase data provides the ability to observe consumer habits of real and potential buyers, forecasting trends in consumer behavior.

AI enables coordination and optimization of transportation. This technology allows for planning trips at the most appropriate times and selecting the best routes. This achieves a reduction in distance and CO2 emissions associated with trips, ensuring an environmentally friendly approach and ecological responsibility in logistics. AI is used in the global cargo drone market. The current state and forecasts of the relevant AI applications are shown in Figure 2.

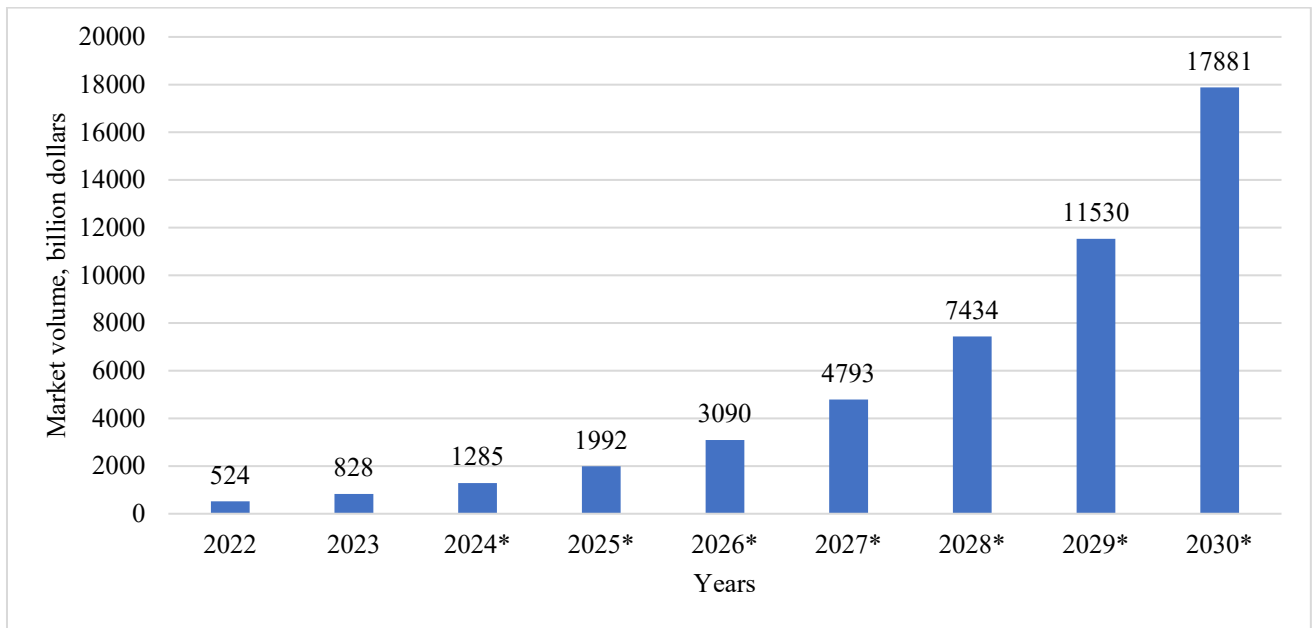


Figure 2 – Total value of the global market for cargo drones in 2023, with a forecast (*) until 2030
Source: developed by the authors from [10]

According to Figure 2, by 2030, the global cargo drone market is expected to double, reaching 17.88 billion US dollars. The most dynamic growth is predicted to occur between 2027 and 2029.

Chatbots created using AI play an important role in the retail sector. These virtual assistants provide customers with a personalized experience, facilitating online shopping and offering assistance in offline stores. AI is also used for quality control. Monitoring with this technology allows for detecting errors and time losses, implementing early corrective processes, and reducing operational costs. Regarding human resources, the use of AI allows for utilizing physical labor and human talent for more skilled and creative tasks, while routine work is subject to automation. One of the main directions of digital logistics is the use of machine learning for optimal decision-making. For instance, it can determine the best route for transportation, efficiently organize a warehouse to meet demand in the next period, or calculate the optimal number of necessary suppliers. Furthermore, machine learning can be applied to clean databases of errors and missing data, mainly in those databases that are manually generated.

The Internet of Things (IoT) is transforming the logistics industry, providing accurate real-time tracking of goods, as well as monitoring their storage conditions, which significantly improves inventory management and overall warehouse efficiency. One of the main advantages of IoT in logistics is that, thanks to radio-frequency identification (RFID), Bluetooth, NFC tags, and GPS, it is possible to determine the exact location of goods at any time, as well as exchange information between participants in the supply chain [19].

The potential of IoT is not limited to inventory tracking but also extends to vehicle maintenance: IoT systems can predict when a vehicle will need maintenance before a breakdown occurs, thus minimizing downtime. IoT devices can track driving patterns and driver behavior, providing feedback that will promote safer driving and improve fuel efficiency.

The IoT architecture of the logistics industry consists of five distinct levels: perception, access, network, support, and applications. At the perception level, data is collected and signals are received through physical devices. The access level responds to sensory requests for transmitting received

data in networks such as 3G, 4G, 5G, WiFi. By sending a signal from the access level to the support level, the network level completes the signaling process. The support level provides data processing tools and platforms. The application level establishes a connection between IoT and its consumers [11].

Big data analysis using artificial intelligence algorithms allows companies to improve decision-making processes, optimize the supply chain, and increase overall efficiency. The expansion of global supply chains generates enormous amounts of data from many sources, requiring advanced analytics for efficient operation and management. Big data allows logistics companies to optimize supply chain operations by providing information on inventory levels, demand forecasts, and real-time shipment tracking. This contributes to more efficient route planning, reduced fuel costs, and shortened delivery times. Customers demand accurate and timely information about order status, delivery times, and product location.

Governments and regulatory bodies are introducing stricter data management and reporting rules. Big data solutions allow companies to comply with these rules by providing accurate and timely data. For example, in May 2024, the European Union's transport regulator emphasized the role of big data in helping logistics companies meet new emission standards. Using big data, logistics companies can improve vehicle utilization, optimize routes, predict maintenance needs, control emissions, and develop low-carbon strategies. The EU's focus on big data signals to the industry that data-driven decision-making is crucial for compliance and competitiveness. By leveraging the power of data, logistics companies not only meet environmental regulations but also gain a competitive advantage [3].

The digitalization of logistics involves moving away from paper and reducing manual operations. This not only contributes to environmental protection but also

optimizes processes, reduces errors, and increases the overall efficiency of the company. The transition from paper to digital documentation in logistics is driven by the globalization of supply chains, and the increasing complexity and acceleration of logistics operations. It's important to understand the difference between digitization and digitalization. Digitization, or digital preservation, refers to transferring information from paper documents into an electronic format for convenient and secure storage and future access to files. Digitalization involves creating documentation in computer applications, intelligent processing and analysis, accumulation in digital repositories, and extensive use of its data to solve various tasks. In the context of supply chain and logistics, digitalization is crucial for optimizing operations, reducing the risk of data loss, and ensuring real-time access to information. The reason why supply chain and logistics companies are increasingly choosing document automation technologies is that they offer several advantages over traditional paper processes. These include increased accuracy and efficiency, reduced costs, improved supply chain visibility, and the elimination of repetitive tasks for staff in favor of other high-value activities. Through digital documentation, logistics companies can ensure they have the necessary information when they need it to make informed decisions and maintain smooth operation of their supply chain [18, p. 119].

One of the main directions in document digitalization is automated document reading and data entry. Specialized software is used for this purpose to automatically extract information from paper documents and input it into digital systems. This eliminates the need for manual data entry, which is time-consuming, can cause errors, and often results in incomplete or incorrect information. There are various document digitalization technologies, including Document Understanding and Intelligent Document Processing, based on the use of artificial

intelligence, machine learning, natural language processing, and advanced optical character recognition mechanisms. These technological solutions provide end-to-end automation of document-oriented processes. By collecting, extracting, classifying, and analyzing information from documents of various types and formats, they enable data integration within workflow automation. Through the automation of document-oriented processes, intelligent document processing can free up time and resources, allowing supply chain companies to focus on core activities, increasing efficiency and reducing costs. For example, in working with images, particularly for recognizing the presence or absence of stamps when processing paper documents, an effective approach is machine learning using convolutional neural networks [16].

Let's consider some types of logistics documents that can be automatically digitized to improve supply chain efficiency and reduce manual data entry errors [1]. These include:

1) Proof of Delivery (POD). POD documents confirm that a shipment has been delivered and serve as the basis for invoicing and customer service. Digitizing PODs helps speed up the billing process and provides real-time visibility of delivery status;

2) Bill of Lading (BOL). This is a legal document that defines the type, quantity, and destination of goods being transported. Digital transformation of bills of lading helps automate carrier selection and routing, improve accuracy and speed of invoicing and payment processes;

3) Bill of Lading Instructions. Many companies offering transportation services receive specific instructions from their clients regarding the information they should include in the bill of lading. This is usually one of the most labor-intensive tasks for those responsible for creating the bill of lading, so digitizing and automating this activity can speed up the overall process of creating the waybill;

4) Packing Lists (PL). These provide a detailed description of the contents of a shipment and serve to ensure the correct items are delivered to the right destination. Digitizing packing lists allows for automating the picking and packing process and reducing the risk of errors;

5) Delivery Note (DDT). A goods transport note or delivery note is a document issued by companies to justify or confirm the transfer of goods, raw materials, or the object of a commercial transaction from one place to another, even in the case of two separate units of the same company. Digitizing transport documents improves logistics processes overall. Choosing to digitize transport documents means a final shift away from paper to simplify and improve processes. Transport documents can physically travel with products or be sent electronically;

6) Invoices. Invoices are an important part of the billing and payment process, and converting them to digital form can help speed up payment cycles, reduce errors, and improve visibility of outstanding payments;

7) Pickup Requests. If a company receives pickup requests via email or PDF files (or other formats), this information is usually processed by a person to initiate the request and create a shipment in the company's transportation management system. This activity can be automated to optimize operations;

8) Air Waybill (AWB). An air waybill is the most important document issued by an airline directly or through its authorized agent. It is a non-negotiable transport document that covers the carriage of cargo from one airport to another. When accepting cargo, the freight forwarder acts on behalf of the airline whose air waybill was issued. Digitizing and automating AWBs can positively contribute to error-free processing of this document;

9) One-Time Quote Requests. For many companies, this can be very complex back-office work, as it is crucial to quickly read and respond to one-time quote requests to attract potential clients. Managing specific quote requests, even if they are sent via email with

audio text, using automated and digital methods can directly impact the number of requests processed and clients acquired;

10) Verified Gross Mass (VGM). This is a document that describes the weight of the cargo, including securing and reinforcement, as well as the tare weight of the container carrying the cargo. It is provided by the shipper to carriers and/or port terminal representatives before the closing date of the loading list. The ability to automatically obtain this information can be crucial for certain transport operations;

11) Cargo Manifest. Provides a summary list of all cargo on board a freight vessel, displayed under the vessel's name and identifying marks. Typically, a cargo manifest contains a list of all bills of lading with specified details and the total quantity of goods being transported. Therefore, as with the bill of lading, it is very important for companies to digitize and automate the processing of the manifest to improve the accuracy and speed of back-office activities.

Thus, by digitizing these and other logistics documents, companies can increase supply chain efficiency, reduce manual data entry errors, and gain real-time visibility into their operations.

The implementation of logistics management technologies requires a strategy tailored to the needs of each company. Defining clear goals, appropriate financial support, attracting and developing digital talents, as well as encouraging continuous improvement are key factors in achieving successful transformation. It is worth considering the benefits of forming integration relationships on a contractual or equity basis between consumers and producers by creating logistics networks, which enables the reduction of logistics and management costs [13].

Conclusions. The digitalization of logistics provides numerous advantages that allow optimizing the supply chain, increasing productivity and efficiency in all areas of the company's activities. The implementation of digital solutions achieves greater integration,

traceability, and flexibility of processes, leading to significant improvements in logistics management. At the same time, digital transformation faces numerous challenges, including a shortage of skilled workforce and the need to enhance employees' digital skills.

Analysis of recent research indicates significant potential for digital technologies in logistics. The implementation of intelligent transportation systems, artificial intelligence, the Internet of Things, and blockchain can significantly improve supply chain management efficiency. This is confirmed by studies of foreign and domestic scientists who emphasize the importance of using advanced technologies to manage flows of raw materials, semi-finished products, and finished goods.

The practice of implementing logistics digitalization shows that main investments are directed towards cloud technologies, artificial intelligence, and machine learning. However, the results often do not meet the expectations of company executives, indicating the need for more in-depth analysis and strategy development to achieve long-term value.

Digitalization of logistics processes, particularly document digitization, contributes to increased accuracy and efficiency, cost reduction, and improved supply chain visibility. The implementation of automated document reading, intelligent data processing, and other advanced technologies allows avoiding errors, reducing information processing time, and focusing resources on the company's core activities.

Thus, logistics digitalization is a significant factor for modern companies seeking to increase their market competitiveness. It allows integration with other company departments, improves product tracking, accelerates customs procedures, optimizes transport costs, and increases flexibility in returns management. Despite the drawbacks accompanying this process, logistics digitalization is necessary to achieve sustainable development and

effective supply chain management in the modern world..

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