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Digital transformation of logistics: the role of artificial intelligence and Big Data in managing transport flows and optimizing loading and unloading operations

Abstract. The digitalization of the economy covers all types of economic activity, among which logistics activities and the implementation of AI and Big Data tools are distinguished.

Problem statement. Comprehensive approach to the study of the digital transformation of logistics (DTL) based on the use of AI and Big Data to manage transport flows (MTF) and optimize loading and unloading operations (OPUO).

Unresolved aspects of the problem. Due to the dynamic development of the processes of DTL, a comprehensive approach based on the use of AI and Big Data to MTF and OPUO requires additional research.

Purpose of the article. Research on the scientific foundations and practical recommendations for MTF and OPUO based on AI and Big Data.

Presentation of the main material. It is noted that the driver of the spread of AI and Big Data tools in logistics is the WEF platform, which also considers the processes of DTL towards green logistics and decarbonization using AI and Big Data tools. The results of research conducted in 2025 among logistics companies in Europe and the USA showed that a quarter of respondents have already integrated AI and Big into their activities, half of them partially use AI and Big, and 57% plan to introduce these tools into their activities. A description of the main companies involved in the development and distribution of applied software solutions for logistics and logistics companies is provided.

Conclusions. A list of the main obstacles (large initial investments, outdated data processing and storage technologies, lack of qualified labor, variability and instability of the regulatory field, costs of maintaining excess inventory in the warehouse) and opportunities (increasing the level of optimization and self-optimization of logistics processes, optimization of resource costs, autonomy of supply chains, real-time processing of large volumes of data and forecasting demand for products over time) in the development of AI and Big Data tools in MTF and OPUO has been formed.

Keywords: *digital transformation, digital technologies, artificial intelligence, big data, logistics.*
JEL Classification L 81; L 86; L 91; R 40
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Introduction. The acceleration and spread of digital technologies in all types of economic activity is changing the paradigm of the economy to a digital model, which means the saturation of production, transportation and service of goods in a different, previously unheard-of form, such as those based on AI and Big Data. Innovations permeate all operational and distribution processes, including logistics. It is logistics processes that play a significant role in the connection between the manufacturer and the consumer (Chukurna et al., 2018; Krushkyn & Nitsenko, 2012). The growth of corporate social responsibility requires transparency of reporting to interested stakeholders, and the introduction of AI and Big Data into the business model strengthens this direction. Therefore, the further development of logistics as one of the key elements in business requires a revision of the classical concept taking into account the requirements of the time.

Literature Review. Dynamic changes in the digitalization of logistics processes under the influence of external factors, including AI and Big Data, lead to the need to form and approve an updated logistics strategy for the development of the enterprise. These and related processes are described in the works of domestic and foreign scientists and specialists. Thus, Raiko (2025) studied the impact of digital transformations on changes in the product policy of the enterprise using AI and Big Data tools. Product policy is a part of the strategic development of the enterprise related to logistics. It is a system of interconnected processes that provide a strategic vision of management regarding the creation of new models, the formation of the assortment of goods and their further sale. Logistics is the next stage, designed to deliver the appropriate quantity and quality of goods on time and to the specified place. There is an indirect connection between the above functional components of the enterprise, which is ensured first by determining the types of goods that are planned to be produced, and then by concluding contracts for their supply.

Marinov and Lisenyi (2024) highlighted the importance of using telematics technologies in logistics processes. Telematics includes information technologies, electrical equipment and tools, telecommunication technologies and vehicles. Telematics as a system provides transport with navigation (GPS), control (sensors) and telecommunication (modems) and appropriate software. That is, with the help of telematics, constant monitoring of the movement and technical condition of the vehicle is carried out as well as optimization of routes and travel time and the possibility of integration with other management systems, etc. It may be concluded that telematics is an important element of modern logistics based on AI and Big Data.

Zavrazhnyi (2023) concludes that the use of AI leads to a reduction in the cost of material and financial resources for transport and logistics. According to the author, AI solves the following issues: eliminating obstacles (choosing the optimal route), connecting with hubs and warehouses (ensuring optimal interaction during loading, unloading and transportation of goods), optimizing the movement of vehicles (planning services for transport), monitoring and checking the technical condition of vehicles (using sensors, motion sensors and software to eliminate technical malfunctions in a timely manner), predicting demand (helps predict potential sales volumes and the need for logistics services). Makhmudova (2025) notes the importance of logistics in global supply chains. She indicates that the management of these processes is moving to the use of agent systems (modeling the relationship between individual management objects within the supply chain), neural networks (predicting demand, optimizing the route, etc.) and genetic algorithms. AI, the author continues, within the supply chain increases the quality of inventory management, demand forecasting, automation of warehousing and logistics processes.

Moroz and Shunevich (2024) drew attention to the introduction of AI into direct and related areas of logistics. They noted significant changes in the field of logistics under the influence of AI on systems such as ERP, CRM, SCM, warehouse management systems (WMS) and transport

(TMS). Scientists have established a reduction in direct labor costs, time, material resources and money from the use of AI in logistics processes.

Buiak and Semenenko (2025), continuing the research of Moroz and Shunevich (2024), proposed the concept of transport systems management. The concept is based on a digital ecosystem, supplemented by the physical movement of vehicles with special software that allows monitoring and managing them in real time.

The above fundamental scientific works significantly expand the understanding and implementation of digitization processes using AI and Big Data in supply chains and logistics processes.

Purpose, objectives and research methods. The purpose of the article is to study the scientific foundations and practical recommendations for managing transport flows and optimizing loading and unloading operations based on AI and Big Data.

Achieving the purpose of the article required the use of appropriate scientific and methodological support, namely the following methods: generalization and abstraction - to determine the key characteristics of the subject of research with the allocation of AI and Big Data; historical and logical research - to analyze the evolution of the issue, draw conclusions and develop proposals; analysis and synthesis - separation and combination of individual elements and the whole to establish a connection; concretization method - to establish a connection between AI and Big Data and logistics processes.

Research results. The driver of the country's economic development is considered to be digitization processes. This is evidenced, in particular, by the Concept of Artificial Intelligence Development in Ukraine (Cabinet of Ministers of Ukraine, 2020) and the Strategy for Digital Development of Innovative Activity of Ukraine for the Period up to 2030 (Cabinet of Ministers of Ukraine, 2024) approved by the Cabinet of Ministers of Ukraine. According to these documents, AI is recognized as the main tool for increasing business efficiency, including logistics. To ensure the effective development of AI, it is necessary to create an appropriate infrastructure, train a sufficient number of specialists, ensure innovative development, carry out the maximum volume of automation processes, and improve the overall logistics management system. An indispensable condition for the implementation of AI is the use of Big Data. The latter, in turn, must be protected from external interference, i.e. potential cyberattacks.

WEF, annually discussing the development of logistics, announced 2025 as the year of AI capabilities in the direction of decarbonization and green logistics processes, operational efficiency, and increased sustainability. The formed scheme “Supply Chain and Transport” has the following connections (Fig. 1).

From the above scheme, it can be seen that the block “Digital Supply Chain Growth” is responsible for AI and Big Data. The latter is also based on the Internet of Things, Cybersecurity, The Digital Economy, The Digital Transformation of Business, Data Policy, Blockchain, Drones (World Economic Forum, 2025). The above elements not only increase operational results, but also ensure resource and time savings, and the efficiency of logistics companies as a whole.

According to forecasts, the global market for artificial intelligence in logistics will grow to $6.5 billion in 2031 and will exceed $4.4 billion in 2024. (Dobosevych, 2025). Despite positive forecasts, logistics companies are at an insufficient level of development in terms of AI and Big Data tools in their activities. The problem of the industry is the lack of complementary and integrated development of companies engaged in the development and implementation of software and logistics companies.

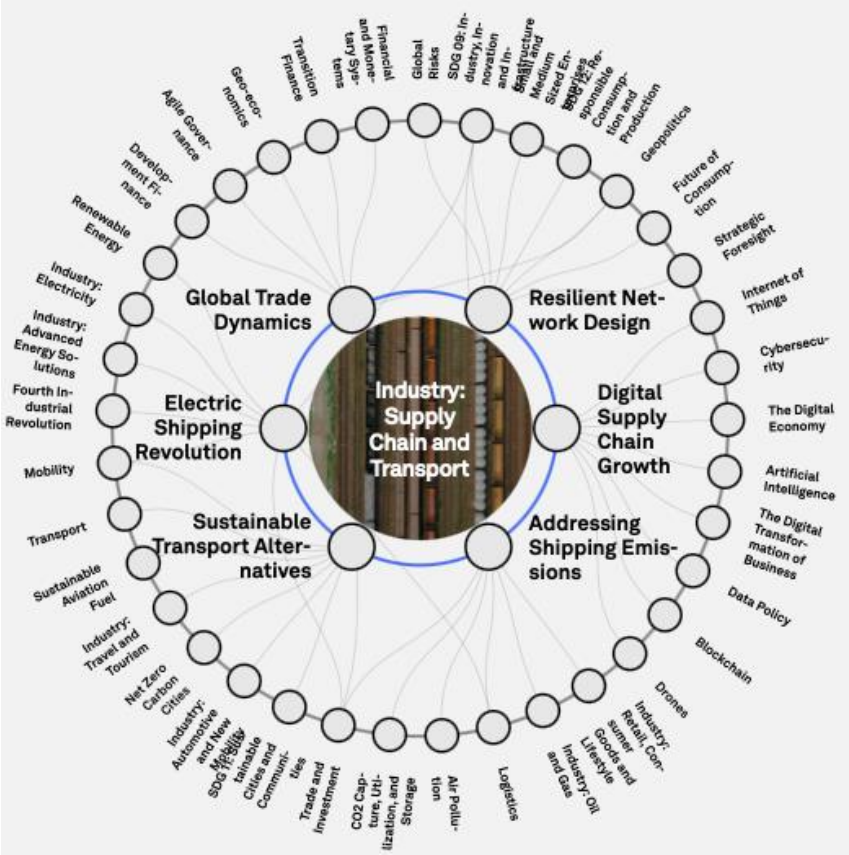

Fig. 1. Industry: Supply Chain and Transport
Source: World Economic Forum (2025).

However, as previously noted, not all companies are ready and can afford to implement AI and Big Data tools. These obstacles are associated, first of all, with an insufficient amount of financial resources available for investment; lack of human resources with appropriate qualifications, experience and knowledge of AI and Big Data; underdeveloped infrastructure for this type of technology; lack of technologies for storing and processing large data sets, etc., delay the full-scale implementation of AI and Big Data tools in traffic flow management and optimization of loading and unloading operations (Nitsenko, Samoilyk, & Hrynko, 2024; Nitsenko et al., 2024). The main obstacles and potential benefits of implementing AI and Big Data tools are presented in Table 1.

Table 1. Obstacles and opportunities from implementing AI and Big Data tools in traffic flow management and optimization of loading and unloading operations

Barriers	Opportunities
Large initial investments	Increasing the level of optimization and self-optimization of logistics processes
Outdated technologies for data processing and storage	Optimization of resource costs (time, fuel, people, money, etc.)
Lack of skilled labor	Using digital twin technology
Variability and instability of the regulatory field	Autonomy of supply chains
Costs of maintaining excess inventory in the warehouse	Real-time processing of large volumes of data
	Forecasting demand for products over time

Source: Developed using Nahirnyi (2025) and own research

A survey of leading logistics companies in Europe and the USA showed that most of them are at the initial stage of implementing and using AI and Big Data. The respondents' answers had a different development pattern (Fig. 2).

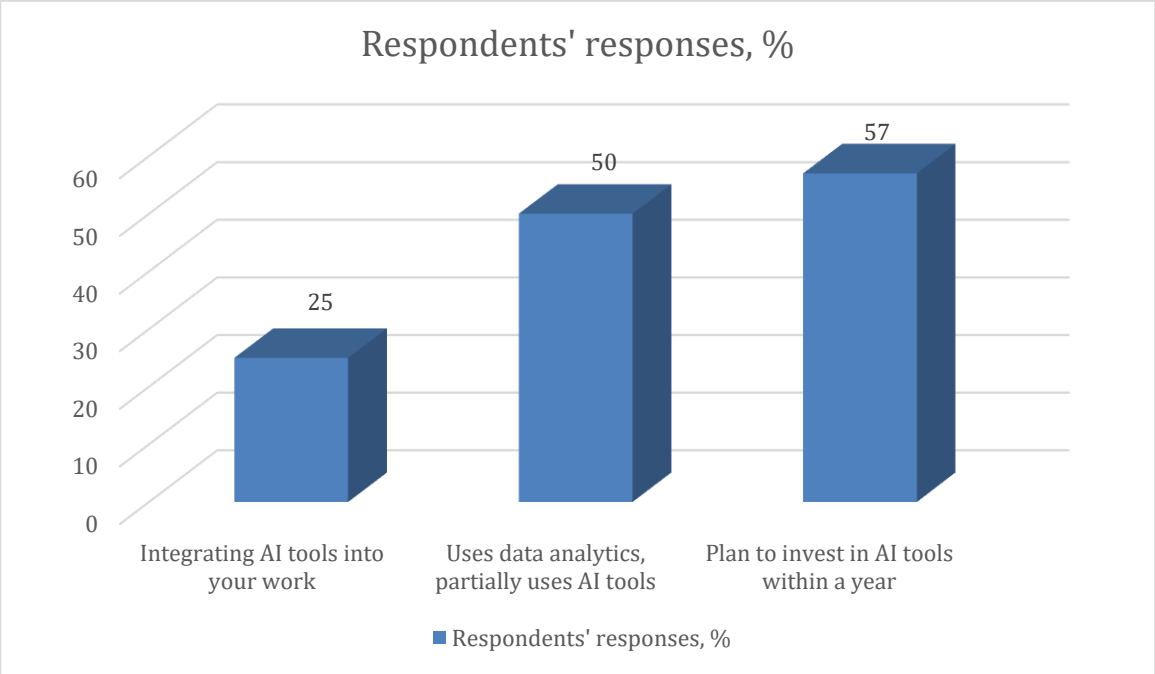

Fig. 2. Results of a survey of logistics companies in Europe and the USA
Source: based on Nahirnyi (2025)

A survey conducted by McKinsey in 2024 showed that on average in the logistics industry, 12.5% of businesses use digital solutions, of which 7.1% are large companies, and only 7.5% of respondents use AI in their activities, of which 3% are large companies (Li et al., 2024).

The data presented show a gradual transition to a new model of logistics operations management, where AI and Big Data will play a key role.

Breakthrough processes in this area were the developments of companies that differ in the stage of completion and integration of AI into logistics processes (Table 2).

Table 2. Stages of development and integration of AI in leading IT companies

	AI Explorers → Early-Stage AI Adoption	AI Augmenters → AI as a Productivity Booster	AI Integrators → AI-Enhanced but Human-Driven	AI Architects → Fully AI-Driven Operations
AI Explorers → Early-Stage AI Adoption	Osa Commerce, Milenow, Pickrr, Ware2Go, Orkestra	↓		
AI Augmenters → AI as a Productivity Booster	→	Konexial, Enmovil Solutions, Shipsy, TrackChain, Parade	↓	
AI Integrators → AI-Enhanced but Human-Driven		→	Greenscreens ai, Neurored, Everstream Analytics, Rippey AI, Kargo, 3SC Solutions, Nautilus Labs, Surgere	↓
AI Architects → Fully AI-Driven Operations			→	7bridges, Einride, Raft, Gatik, Vorto

Source: Based on Omden (2025).

The formed set of companies ensures the implementation of AI to increase the level of autonomy of vehicles, optimize the time spent on delivering goods and funds, transparency and quick access to data, etc.

The main areas of work in IT companies specializing in managing transport flows and optimizing loading and unloading operations are (AI Superior, 2024):

1. SNAP Account: integrated systems for managing vehicle fleets, parking networks and their safe parking, analytics and real-time data monitoring to optimize the size of the used fleet.

2. Optibus: increasing the level of operational efficiency of companies, analytics and real-time data monitoring, optimization of public sector transport.

3. Covariant (works in various areas, including logistics): AI for robotics, deep learning, automation of operational processes.

4. Altana (works in various areas, including logistics): applies machine learning, implements data analytics, improves transparency, visibility, and sustainability of the supply chain based on AI.

5. NoTraffic: offers AI-based traffic management in the city, real-time traffic light optimization, and provides communication between autonomous and connected cars.

6. Locus Robotics: offers the latest solutions for automation of warehouse work based on robotics, provides autonomous mobile robots with sophisticated navigation systems, and the ability to integrate the proposed solutions into an existing management system.

7. LogiNext: provides automation of route planning, resource planning, and fleet management processes, and provides real-time vehicle usage monitoring.

8. Venti Technologies: focuses on autonomous vehicle technologies, ensures the safety, sustainability and efficiency of vehicle use, and implements machine learning algorithms with reliable equipment.

Examples of well-known logistics companies that have implemented AI and Big Data in their activities include (AI Superior, 2024):

1. Baltic Transline: All types of transportation and logistics services using AI tools. The company's services include sea, air and road transportation to different countries of the world. Baltic Transline also provides responsible storage of goods in its own warehouses. The entire range of operations is permeated with monitoring and control systems, which increases the effectiveness and efficiency of management decisions in cargo delivery chains.

2. Gatik: The company provides mid-range logistics services (transportation of products between distribution centers and stores, supermarkets, shopping centers). It uses autonomous vehicles equipped with motion and control sensors, an AI system. The integration of the above tools ensures timely, safe, resource-efficient delivery.

As it can be seen, the digitization of processes, including the use of AI and Big Data tools, in managing transport flows and optimizing loading and unloading operations tends to gradually increase. This is stated, in particular, in the McKinsey study (Fig. 3).

The basic characteristics of the development of the studied market are transportation, warehouse technologies and planning. The higher the level of development of the given technology, the more widespread it is, if it is in the middle – the beginning of distribution, in the lowlands – the level of distribution is too low, in the stage of development. Thus, in the field of transportation, digital procurement of goods (14), asset tracking and intelligent data analysis (13) and digitalization and management (12) are prominent; such processes as the use of drones for delivering goods (3), augmented reality for drivers (2) and transport running on hydrogen (1) are at the beginning of their development. Warehouse technologies have become the most widespread solutions for delivering goods to a person based on AGV (14), management of the efficiency of distribution centers (13) and individual productivity in real time (12); they are at the stage of innovative development. Data analytics and automated root cause analysis for efficiency management (10) and automated replenishment (9) are widely implemented in planning processes, while real-time constraint-based estimation (2) and closed-loop planning (1) are available for the promised ones at the development stage.

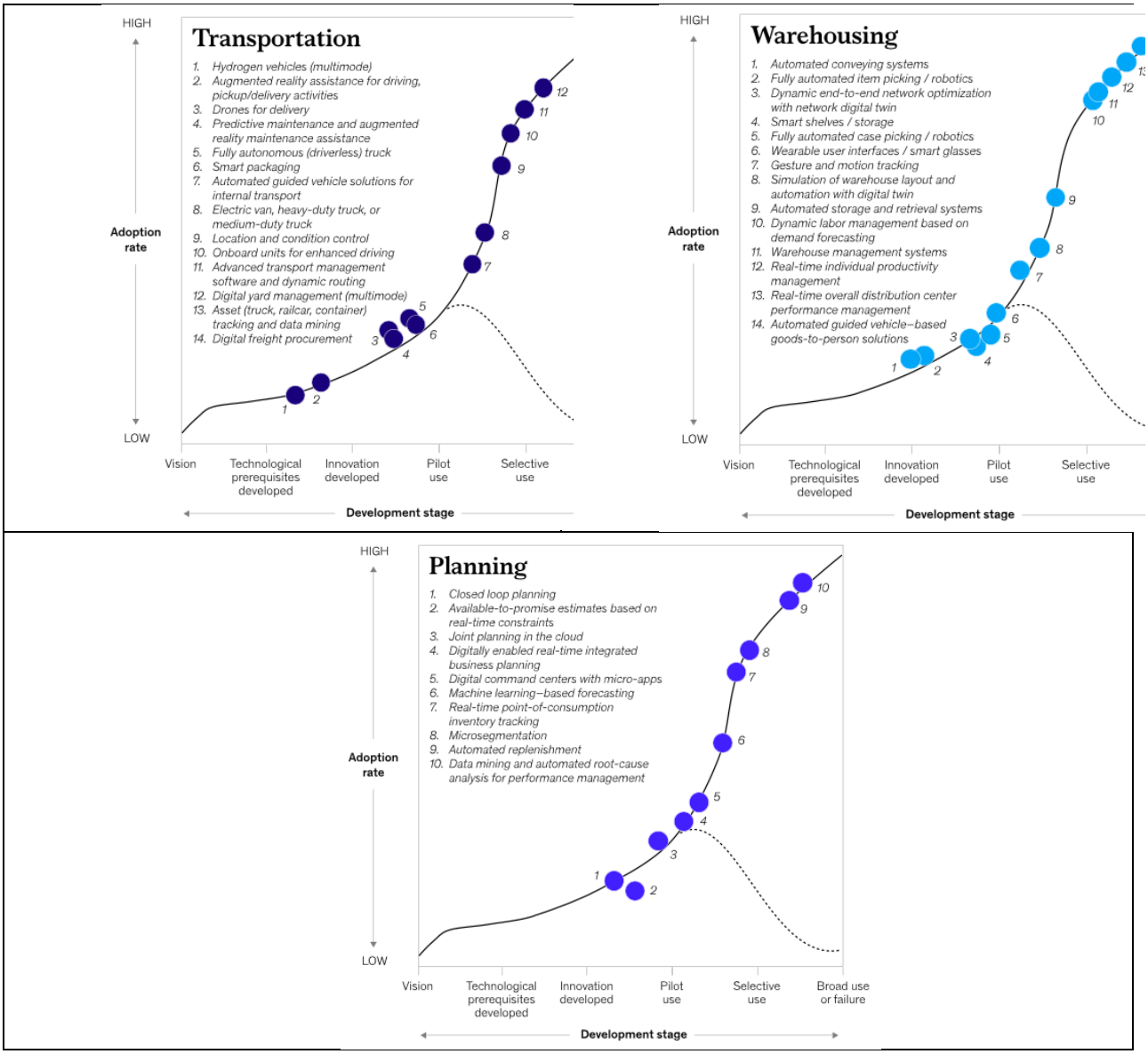

Fig. 3. Scenarios for the development of logistics based on digital technologies
Source: based on Gosling et al. (2023).

The conducted research has shown the widespread use of AI and Big Data tools in the management of almost all areas of work in logistics activities. Thus, the use of AI in routing will reduce fuel consumption by 15% and more; intelligent maintenance systems will reduce the time and costs of repairs and maintenance by 20-30% and will increase the service life of vehicles; the use of telematics and autonomous vehicles will reduce the number of road accidents by at least 40%; anomaly detection tools will allow maintaining the temperature regime in refrigerated trucks and monitoring the quality of vehicle management; Warehousing systems will eliminate delay time, increase the reliability and timeliness of cargo delivery to the client, and reduce the time spent on sorting goods (Dobosevych, 2025).

Discussion. The conducted research made it possible to identify the main directions of development in the management of transport flows and the optimization of loading and unloading operations. This is confirmed by the fact that, according to Marinov and Lisenyi (2024), modern Ukrainian realities do not allow logistics companies to quickly adapt to market needs. Therefore, logistics companies lag behind the required pace of development, which affects the efficiency of the entire supply chain. There are time inconsistencies in deliveries, increasing customer dissatisfaction with cooperation, deterioration of reputation, etc.

In this regard, Aubakirova recommends developing and implementing an optimization strategy in the management of transport flows and the optimization of loading and unloading operations using big data analytics. Using the example of companies, the scientist developed a program for optimizing the route of cargo delivery using clustering algorithms. Indeed, the proposed innovations can significantly improve all logistics operations within the company.

In this regard, Buiak and Semenenko (2025) emphasize the need to develop new models of managing the transport system in order to reduce unnecessary costs of time, money and other resources, contribute to increasing the efficiency of the use of vehicles and adapting to the needs of a changing environment. Therefore, an important condition for achieving the specified priorities is the use of AI and Big Data tools in managing transport flows and optimizing loading and unloading operations. Indeed, the variability of the environment and operating conditions requires managers to take new approaches to solving the existing problem, which can be solved in an integrated manner in conjunction with AI and Big Data.

Pozniak and Melnyk, in turn, add about errors that arise during the operational activities of logistics companies. Such situations cause confusion in the types of goods to be delivered, time delays, unnecessary expenses, etc., so the transition to the use of AI and Big Data is quite appropriate and justified.

Conclusions. The study characterizes the current state of logistics process management as transformational. The development of a new technological order in the world has not bypassed logistics operations. At the current stage, there is a progressive transition from the traditional logistics model to a new one based on AI and Big Data tools. WEF declares a transitive passage to green logistics and decarbonization, which will be accompanied by an increase in the level of sustainability and efficiency. If in 2024, according to McKinsey research, only 7.5% of the surveyed companies used AI, then in 2025, a survey of logistics companies in Europe and the USA showed a 25% implementation level. However, the lack of cooperation between developers of IT solutions and software with manufacturers and logistics companies does not allow the full potential of this sector to be revealed. Currently, AI and Big Data tools are used by large companies with sufficient financial reserves. The conducted scenario modeling of the development of transportation, warehouse technologies and planning showed that some technologies are at the innovation and pilot stages, at the selection stage and at the stage of widespread use, which does not allow using the existing potential in managing transport flows and optimizing loading and unloading operations based on AI and Big Data.

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Цифрова трансформація логістики: роль штучного інтелекту та Big Data у керуванні транспортними потоками та оптимізації вантажно-розвантажувальних операцій

Анотація. Цифровізація економіки охоплює усі види економічної діяльності, серед яких виділяють логістичну діяльність та впровадження інструментів AI та Big Data.

Постановка проблеми. Комплексний підхід до дослідження цифрової трансформації логістики на базі використання AI і Big Data для керування транспортними потоками та оптимізації вантажно-розвантажувальних операцій.

Нерозв'язані аспекти. У зв'язку з динамічним розвитком процесів діджиталізації логістичних процесів потребує додаткового дослідження комплексний підхід на базі використання AI і Big Data для керування транспортними потоками та оптимізації вантажно-розвантажувальних операцій.

Мета статті. Дослідження наукових основ та практичних рекомендацій щодо керування транспортними потоками та оптимізації вантажно-розвантажувальних операцій на базі AI і Big Data.

Основний матеріал. Зазначено, що драйвером поширення інструментів AI та Big Data у логістиці є майданчик WEF, на якому також розглядають процеси трансформації логістичних операцій у бік зеленої логістики та декорбонізації з використанням інструментів AI і Big Data. Результати проведених досліджень у 2025 р. серед компаній логістичної галузі Європи та США продемонстрували, що чверть опитаних вже інтегрували AI і Big у свою діяльність, половина – частково використовують AI і Big та 57% - планують запровадити дані інструменти у свою діяльність. Приведено характеристику основних компаній, що займають розробкою та поширенням прикладних програмних рішень для логістики та логістичних компаній.

Висновки. Сформовано перелік головних перешкод (великі початкові інвестиції, застарілі технології щодо обробки та зберігання даних, нестача кваліфікованої робочої сили, мінливість та нестабільність нормативно-правового поля, витрати на утримання зайвих запасів на складі) та можливостей (підвищення рівня оптимізації та самооптимізації процесів логістики, оптимізація витрат ресурсів (часу, палива, людей, коштів тощо), використання технології цифрових близнюків, автономність ланцюгів поставок, обробка в режимі реального часу великих обсягів даних та прогнозування попиту на продукцію у часі) у розвитку інструментів AI і Big Data у керуванні транспортними потоками та оптимізації вантажно-розвантажувальних операцій.

***Ключові слова**: цифрова трансформація, цифрові технології, штучний інтелект, масиви великих даних, логістика.*

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