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INNOVATIVE TECHNOLOGIES IN THE LOGISTICS SYSTEM

Nadiia Reznik. «Innovative technologies in the logistics system». *This article highlights the importance of the latest technologies and innovative logistics as the most effective element of the logistics activities of enterprises. The essence of the most modern and progressive technologies is described in detail, their advantages and features of implementation in real-time conditions are determined. The impact of these technologies on logistics and supply chains is analyzed. It has been established that the participants of the logistics chain are able to create a transparent and effective system of transaction recording, asset tracking and documentation management using the most promising innovative technologies in the logistics field. The effects that the subjects of the logistics chain receive from the introduction of the latest technologies are outlined. It has been proven that the use of progressive innovations in logistics can ensure the growth of the effective activity of any enterprise, reduce the total costs for the implementation of flow processes and improve the quality of customer service as a whole.*

Keywords*:* innovative logistics, latest technologies, logistics system, innovative technologies, logistics process management

Надія Рєзнік. «Інноваційні технології у логістичній системі». *У статті висвітлено значення новітніх технологій та інноваційної логістики як найбільш ефективного елементу логістичної діяльності підприємств. Детально описано сутність найсучасніших і прогресивних технологій, визначено їх переваги та особливості впровадження в умовах реального часу. Проаналізовано вплив цих технологій на логістику та ланцюги поставок. Встановлено, що учасники логістичного ланцюга здатні створити прозору та ефективну систему реєстрації транзакцій, відстеження активів та управління документацією, використовуючи найбільш перспективні інноваційні технології у сфері логістики. Окреслено ефекти, які отримують суб'єкти логістичного ланцюга від впровадження новітніх технологій. Доведено, що використання прогресивних інновацій в логістиці здатне забезпечити зростання ефективної діяльності будь-якого підприємства, знизити сукупні витрати на реалізацію потокових процесів і підвищити якість обслуговування клієнтів в цілому.*

Ключові слова: інноваційна логістика, новітні технології, логістична система, інноваційні технології, управління логістичними процесами.

Introduction. Technological innovation plays an increasing role in all sectors of the economy, and logistics and supply chain management in the enterprise cannot remain aloof from this process either. And since large volumes of data are actively used in the field of logistics, which are stored separately and in different programs, and are very often entered manually, it is possible that logistics

will benefit more from the introduction of new innovative ways of working.

Innovations in the logistics sector are determined not only by the desire of logistics companies to implement new technologies in order to keep up with the development of the industry. A significant role in this process is played by representatives of trading businesses and large industrial enterprises, which strive for their goods and services to reach consumers faster and at lower costs.

Logistics trends depend on significant changes caused by the introduction of logistics technological solutions into business processes. In particular, next-generation logistics technologies make global supply chains more customer-oriented and sustainable, and the automation of logistics processes significantly increases the productivity and efficiency of the work process. Therefore, increasing the transparency and traceability of the supply chain is essential to create a flexible and dynamic relationship between the various stakeholders.

According to Research and Markets, the market was valued at USD 9407.5 billion in 2023 and is likely to grow to USD 15978.2 billion by 2032, representing a CAGR of 6.4%. In particular, technology in logistics is constantly evolving, and in 2025 we can expect major changes, from new logistics innovations to changing consumer behavior.

Analysis of recent research and publications. Many Ukrainian and foreign authors studied the development and implementation of logistics innovations. In particular, Smirnova N.V. studied the works of scientists who studied different approaches to defining types of logistics innovations and directions of innovative development in logistics [1, p. 169–180]; Boldyreva L.M. on the basis of links of the logistics chain and functional types of logistics classified logistics innovations [2, p. 18–23]; Malukalo O.O. formed the principles of logistics management and effective logistics support [3, p. 18–23]; Rudenko S.V., Pylypchuk K.M. studied the main characteristics of the concept of supply chain management and logistics system [4, p. 95–102]; Podra O.P., Gomza K.I. formulated the main technologies of automation of warehouse activities of enterprises [6, p. 70–78]; Fedkovich I.V. determined directions for improving logistics activities at the enterprise [7, p. 111–113]; Mishchuk I.P. and Mariy O.T. studied the main areas of management of logistics business processes [8, p. 153–159]; authors Smerichevska S.V. and Kryvoruchko G.O. formulated the methodological and theoretical foundations of effective management of logistics processes [10]; Mayorova I.M. used a strategic management approach to identify logistics innovations, basing them on four logistics concepts [11, p. 326–348]; Pity M.S. noted that the management of innovations in logistics should be formed on the basic logistics circuit, which includes units of supply, transportation, storage and sales [12, p. 59]. Mulyarchyk M.B. and Krykavska I.V. emphasized the important role of information technologies in logistics innovations [13, p. 73]; Testard M. (Testard M.) claims that «innovations in the field of logistics will provide logistics enterprises with significant opportunities to position themselves as value creators and change their operating models towards greater flexibility» [14]; Mitchell-Keller L. (Mitchell-Keller L.) notes that innovative logistics systems allow retailers to track the location of goods in real time and compare planned and actual logistics flows for a timely response to force majeure [15]; Sigida L.O. and Tsunenko A.M. emphasize that effective management of logistics activities ensures the production process, covering all stages - from the supply of raw materials to the distribution of finished products, which allows to deliver products to the consumer with minimal costs [16, p. 112]. Mykhalytska N.Ya. and Veresklya M.R. point out that fierce competition requires new approaches to planning and managing product flows, based on the principles of logistics, which helps to increase the competitiveness of enterprises [17, p. 7].

Materials and Methods. The theoretical and methodological basis of the study were the provisions and developments of domestic scientists, as well as foreign experience in the field of logistics, theory and practice of management in logistics, along with the author's personal assessments. Analytical and abstract-logical methods were used during the research. The use of methods of analysis and synthesis made it possible to determine innovative forms of logistics management that are currently being implemented in the field of logistics. The method of structural comparative analysis helped to determine the main components of the digital supply chain management system model. The method of expert assessment contributed to the identification of key areas of logistics activity of enterprises that require the implementation of innovative approaches and improvement of the logistics management system.

Presentation of the main results. In today's world, where the speed and efficiency of transportation play a key role, logistics companies of Ukraine have a significant impact on the development of the national economy. They ensure the uninterrupted movement of goods between producers and consumers, which contributes to the stable functioning of various industries. Logistics is an important component of the supply chain, which covers not only the transportation, but also the storage, processing and distribution of goods.

But advances in technology aren't the only big changes affecting the industry. New shipping regulations, growing global tensions, trade wars, the pandemic, martial law in Ukraine, the spread of e-commerce and online retail require logistics companies to quickly adapt to changes in the market environment.

In the conditions of globalization and growing competition, efficient logistics is becoming a decisive success factor for many enterprises. They are able to offer comprehensive solutions that include all stages of the logistics process, from planning to execution control.

Today, logistics companies of Ukraine face a number of challenges that require constant improvement and innovation. One of the main challenges is the state of the infrastructure. Despite significant investments in road and railway modernization, there is a need for further improvement of the transport network. An important aspect is the development of port infrastructure, which plays a key role in international trade.

In addition, global changes in the logistics industry, such as the transition to a green economy and the introduction of energy-efficient solutions, also create new opportunities for Ukrainian logistics companies. The use of alternative types of fuel, electric vehicles and the implementation of energy management systems can reduce the environmental impact and lower fuel costs.

Digitalization is another important trend that opens up new opportunities for logistics companies. The use of the Internet of Things (IoT), blockchain technologies and process automation helps to increase the efficiency of supply chain management. These technologies make it possible to reduce the risks associated with the human factor and ensure high accuracy of logistics operations. Companies in logistics and supply chains must continue to prepare for all of these big changes by leveraging innovation.

Let's analyze these innovations in logistics activities at enterprises carrying out the transportation of goods:

1. Internet of things.

IoT involves connecting physical devices to track and transmit data over the Internet without human intervention. The use of IoT in logistics improves transparency at every stage of the supply chain and increases the efficiency of inventory management. In other words, the integration of IoT technology into logistics and supply chain operations can increase efficiency, transparency, and real-time visibility of goods. For example, during

transportation, IoT makes it easier to monitor temperature and humidity for sensitive goods, thus maintaining product quality and compliance with regulatory standards.

The impact of the IoT on the logistics industry extends even further, allowing logistics companies to use predictive analytics to anticipate fluctuations in demand. Such solutions also optimize routes and planning, and minimize environmental impact by tracking fuel consumption. This contributes to sustainable and environmentally friendly supply chain practices.

Ambrosus has created an IoT network for the food and pharmaceutical supply chain. The network provides data analytics tools, shared sensors, distributed ledgers, and databases for supply chain management. Fleetroot's IoT platform, which is used by companies, also allows them to manage their fleets. With the help of sensors and devices implanted in the vehicle, the platform monitors the functioning of the vehicle and notifies the system [20].

2. Artificial Intelligence.

Logistics companies are responding to demand fluctuations in advance using artificial intelligence and machine learning algorithms. For example, AI can help managers plan supply chain processes and reduce inventory losses by forecasting. In addition, companies are using AI to optimize route planning and consolidate cargo, which in turn reduces fuel consumption and carbon dioxide emissions, supporting overall sustainability efforts. Customer service and supply chain communication have also been improved with the help of chatbots and virtual assistants managed by artificial intelligence.

AI-powered robots and drones increase efficiency and reduce labor costs for tasks such as inventory counting and last-mile delivery. Additionally, to improve the security and compliance of logistics operations, AI-driven robots are used for risk assessment and fraud detection systems. This allows logistics companies to automate security tracking and protect shipments, reducing financial losses [21].

Australian firm Adiona has developed an AI-based service (OSaaS) for optimization software to help businesses improve logistics processes and reduce costs. Using machine learning, the system can predict factors such as demand, weather and traffic. That is, we can claim that this approach allows reducing the number of people needed for manual input.

Insite, a New Zealand-based startup that creates AI-based software solutions for price and demand forecasting, as well as flow and process optimization, mainly serves the retail industry. This platform offers tools for risk assessment and demand forecasting. That is, it contains modules for collecting and combining real-time process data. This allows managers to be well-prepared to manage product replenishment and ensure that information is up-to-date.

3. Robotics.

The integration of robotics into logistics increases the speed and accuracy of supply chain processes and reduces the likelihood of human error. Robots ensure long-term uninterrupted operation and increase productivity compared to human labor. However, robots do not replace people, but complement their work, increasing overall efficiency.

Physical robots, i.e. collaborative robots (cobots) and autonomous mobile robots (AMRs), are used to pick and transport goods in warehouses and warehouses. In addition, software-based robots, by performing repetitive and routine tasks, allow people to free up time for more complex and important functions [20].

According to the «Global Customer Report», testing of robotics in warehouses increased the efficiency of operations by 18%. Among the companies that are leaders in the use of robots in warehouses, we can highlight: Amazon, IKEA, Tesla, DHL, Coca-Cola and others.

4. «Last mile» delivery.

Challenges such as traffic congestion, customer preferences, and regulatory complexities are driving significant technological changes in last-mile delivery services. Companies are looking for alternative delivery methods, such as drones and autonomous robots, that can provide more efficient delivery. Micro fulfillment centers strategically located in urban areas are reducing delivery times, and crowdsourced delivery platforms are utilizing local resources for flexible.

Instant or same-day delivery meets consumers' growing demands for speed. What's more, it's intelligent hidden cameras, data-driven routing, and sustainability initiatives that contribute to increased convenience, efficiency, and environmental responsibility. Improved experience and collaborative logistics are key tools to meet changing customer expectations and optimize efficiency [23].

The Irish company Manna provides restaurant chains with a delivery service using a fleet of drones. These drones can fly up to 90 meters at a speed of 90 km/h. Drone delivery helps to solve the problem of last-mile congestion by allowing drones to reach remote areas, reducing delivery times and costs.

In 2021, the Ukrainian company Nova Poshta, which changed its name to Nova, successfully tested the delivery of a parcel by drone from Kyiv to Lviv. It is expected that the company «Nova» can create an engineering firm that will deal with solving the problems of transporting goods with the help of drones. The company is currently testing drones from several Ukrainian manufacturers: Ukrspecsystems, Aerodrone and Betterfly. Drones have the potential to deliver goods to cities and regions with underdeveloped transportation infrastructure and areas with no quality roads. In this way, last-mile delivery enables on-demand, pickup or courier companies to reduce out-of-pocket costs and reduce time to market.

5. Warehouse automation.

Automated warehouse technologies include automated guided vehicles (AGVs), robotic picking systems, automated storage and retrieval systems (ASRS), and wall-mounted kits. They optimize warehouse operations and additionally affect the last-mile delivery phase. Warehouse automation reduces errors and increases productivity, and ensures that products are accurately picked, packed, and ready for shipment.

At the same time, synchronizing advanced automation solutions with last-mile logistics systems ensures a seamless flow of goods, resulting in faster and more accurate delivery. Thus, warehouse automation becomes an integral part of the larger logistics ecosystem, optimizing logistics operating costs and improving last-mile delivery [20].

The French company Exotec is creating Skypod, an automated e-commerce warehouse optimization robot that optimizes storage space by using a vertical storage method to increase warehouse height to 12 meters.

ASRS software is used in the management of storage of products and materials in automated warehouses, it improves the use of space and does not require the involvement of manual labor for operation, together with allows to reduce the total operating costs and increases safety.

6. Blockchain.

The decentralized blockchain ledger ensures the integrity and immutability of transaction records. This system addresses the need for secure and tamper-proof documentation in complex logistics supply chains, increasing security, transparency, and efficiency. Thanks to the blockchain, participants in logistics operations can receive accurate information about the movement and status of goods in real time, ensuring full visibility and traceability.

A key feature of blockchain is smart contracts, which can automate and optimize various aspects of logistics, including customs clearance and payment processing. These

self-executing contracts speed up approvals and reduce processing times at checkpoints, speeding up the entire supply chain. With the spread of blockchain, trust between participants increases, administrative burden decreases, and the safe and efficient flow of goods around the world is ensured [19].

Steamchain proposed a blockchain platform that uses World Trade Logistics (WTL) smart contract systems to simplify payment processes. With WTL smart contracts, you can make B2B payments and prevent fraud, and together with you ensure an immutable record of all transactions. In addition to eliminating currency conversion costs, WTL smart contracts allow companies to minimize the costs associated with currency fluctuations.

7. Big data and analytics.

Warehouse operations benefit from data-driven insights to improve productivity by optimizing layout design, inventory placement, and order picking strategies. Logistics companies use big data to monitor location and weather conditions in real time, enabling them to dynamically adjust routes and improve delivery plans, thereby reducing delivery times and fuel consumption.

Market data analysis facilitates strategic decision-making that optimizes logistics service providers' relationships with suppliers of goods, adjusts pricing strategies, and manages inventory levels more effectively. In addition, the integration of big data and analytics enables the creation of comprehensive risk management reports, identifying anomalies and trends, allowing companies to proactively address potential disruptions and vulnerabilities in the supply chain.

The proposed AI solution of the American company Nautilus Labs helps maritime companies to reduce fuel consumption and increase efficiency. This software analyzes historical travel data and predicts the optimal speed and fuel consumption. The data generated by the cloud platform about the ship's characteristics subsequently helps to optimize fuel costs.

FACTIC, an American startup, has found a solution for the food and beverage industry and offered a SaaS platform for predictive analytics. FACTIC uses data mining and AI methods to predict future sales by analyzing data from internal and external sources. The platform predicts demand fluctuations and makes data-driven decisions to automate procurement and provides tools to optimize inventory through automatic replenishment.

8. Cloud computing.

Cloud-based SaaS solutions are transforming the logistics landscape by providing scalable and cost-effective solutions. Logistics companies are using cloud-based SaaS platforms to provide pay-per-use models that reduce the need for significant investments in IT infrastructure. This approach minimizes financial risks and allows businesses to allocate resources more efficiently. Cloud-based applications also simplify global logistics management by eliminating geographic restrictions.

In addition, cloud-based logistics solutions can solve communication problems, thereby providing secure and accessible platforms for collaboration. By providing centralized communication, supply chain participants can easily share data and information, improving coordination and responsiveness. In addition, cloud integration simplifies the collection of data from different management systems to analyze and optimize overall processes. A data-driven approach leads to better decision-making, increased efficiency, and improved customer service.

ESTOKO Logistics is a Spanish startup that develops cloud-based logistics solutions and provides warehousing services. It allows companies to centrally and securely manage logistics storage. In addition, the startup's cloud platform offers dashboards and reports to better manage warehouse operations and integrates with enterprise resource planning (ERP) systems.

The use of blockchain on the platform further ensures end-to-end data transparency, increasing the trust of

stakeholders throughout the supply chain. Together, these features allow companies to manage multiple warehouses and unify billing, while reducing transportation costs and shortening service times to destinations.

SaaS Inet is a cloud-based transportation management system created by Belgian startup Alpega to provide a full range of transportation services that connects manufacturers with a wide network of logistics service providers in real time. Inet TMS automates logistics processes and integrates transportation needs into one system. In addition, this software solution allows for shipment tracking via a mobile application. The cloud-based platform allows Alpega to release software updates to customers on a quarterly basis, as opposed to on-premises programs that are updated annually.

9. Autonomous vehicles.

One of the upcoming trends in logistics is autonomous vehicles, which increase safety by eliminating the risk of human error, such as driver fatigue and distraction.

This gives the company a guarantee of safe and reliable transportation of goods, thereby reducing the costs associated with possible accidents. They are used both in the first and last mile. By operating continuously, autonomous vehicles help improve supply chain efficiency and enable fast and flexible delivery, especially in cities. Another benefit of autonomous vehicles is promoting environmental sustainability. With the help of the methods they use: dilution on long routes, reduction of wind resistance and fuel consumption, the efficiency of fuel use increases. In addition, the use of advanced artificial intelligence technologies makes it possible to reduce fuel consumption and emissions by optimizing travel routes to avoid traffic jams and choose the most efficient routes [23].

The Spring X1 autonomous SUV from the German startup Spring transports goods using predictive intelligence. The modular trailers that Spring's autonomous vehicles are equipped with can be customized depending on their application, such as mobile warehouses, food and cargo delivery.

For example, South Korean self-driving cargo transportation startup Mars Auto has developed AI-based software for self-driving vehicles that includes tools for mapping the environment, monitoring, and directing vehicles to the correct cargo bay. In addition, it helps shipping companies deliver cargo efficiently, reliably, and safely without human driver intervention.

10. Elastic logistics.

During periods of fluctuating demand, companies use elastic logistics to manage their operations efficiently, allowing them to quickly increase or decrease their supply chain operations in response to market changes. During periods of high demand, companies can quickly increase their production, transportation, and warehousing capacity to meet growing customer orders. Conversely, during less active periods, capacity can be reduced to avoid unnecessary costs of excess resources.

This approach prevents underutilization of ships and vehicles by adjusting capacity to demand, which reduces costs and environmental impact. Elastic logistics is able to mitigate warehouse and storage constraints by dynamically adjusting space requirements, which in turn solves the problem of excess inventory by allowing companies to adjust inventory levels to actual demand, reducing operational costs and moral hazard, product obsolescence [23].

Shorages, a startup based in the United Arab Emirates, is a B2B on-demand warehousing marketplace for small and medium-sized enterprises (SMEs). Through its extensive network, Shorages helps businesses find short-term storage space. In other words, the platform allows owners to rent unused space in their warehouses to meet short-term needs, and offers pay-per-use, on-demand storage, and order fulfillment services to customers.

The GlassWing platform offered a wide range of commercial vehicles for freight transportation on demand. It has created a

network of logistics services that connects cargo owners with carriers. Using artificial intelligence technologies, the startup provides solutions such as real-time tracking and alerts, route optimization, and individual cargo safety reports, thereby reducing transportation costs.

11. Green Logistics.

Sustainable development is a movement that has spread to many industries, including logistics. Currently, more and more businesses are implementing various technologies to reduce their negative impact on the environment. The high dependence on fossil fuels, the impact of transportation, the constant carbon footprint and the need for human intervention, among many others, are key factors in this trend [23].

Amazon recently announced its «Climate Pledge» to achieve its environmental goals. It aims to engage other companies in its efforts to become carbon neutral by 2040 and support renewable energy sources. To confirm its intentions, Amazon has signed an agreement with Rivian for the production of electric vehicles for the supply of 100 thousand electric vans.

Deutsche Post, another of the world's largest courier companies, has also allocated $552 million to develop light transport electric vehicles and micromobility units. A leader in sustainable packaging solutions, CJ Logistics has implemented zero-waste practices through minimal packaging and environmentally friendly materials, developing innovative packaging materials and smart packaging solutions.

CJ Logistics, in collaboration with partners such as Moorim Paper, has integrated environmentally friendly paper filling materials into logistics operations and reduced the use of plastic. Switching all packaging materials to environmentally friendly alternatives not only protects the environment, but also increases productivity.

12. Digital twins are an accurate simulation model of an existing supply chain that uses operational data and information about the state of its real prototype to determine its future behavior. This technology allows you to create virtual copies of objects or processes and has a wide range of applications in logistics, in particular in warehouses – for modeling premises, planning and adjusting routes, schedules and reverse logistics processes [5; 6]. Managers understand that real goods will always differ from their computer models, which do not take into account the current state of parts, and that logisticians can quickly change specifications to meet consumer needs.

Datumix from the United States has developed a virtual 3D simulation for the main equipment. It uses machine learning to create digital doppelgangers that allow real-time monitoring of hardware performance before implementing algorithms. Data from these 3D models, along with artificial intelligence, is used to service the equipment.

The German company Cognition Factory offers the CognitiveFlow solution, which is based on artificial intelligence for modeling warehouses. This software is designed for planning, designing and managing mobile robots and material handling systems in the warehouse. CognitiveFlow integrates data from both local sources and other systems.

13. Augmented Reality.

In 2024, augmented reality (AR) will transform logistics, enabling real-time statistics and improving operational efficiency. AR-based wearables provide instant access to data, which increases productivity and reduces errors. AR also improves security by monitoring shipments and resolving issues quickly, which in turn improves customer satisfaction.

With the Vision Picking pilot project, DHL is using augmented reality (AR) in logistics. This project integrates AR smart glasses into warehouse processes, providing employees with digital picking lists and optimized routes that reduce movement. Thanks to the ability to scan barcodes, smart glasses guide employees to the right places and items on the shelves. Such an implementation allows to increase the efficiency of picking by 25%,

improve productivity and reduce the number of errors.

With all the advantages of introducing new technologies into logistics activities, there are certain problems and disadvantages that should be taken into account, in particular:

1) coordination. When carrying out international transportation, certain technical failures may occur during the coordination of logistics activities. As a rule, the most frequent problems are: language, schedule, cultural changes, mentality, introduction of new technologies at different rates in different countries of the world.

2) large and multinational companies. The essence of this problem is that the logistics sector includes very large companies that have a huge influence on this segment of the market because they have a lot of equity capital that allows them to introduce new technologies faster and offer cheaper services. This is how they can create a threat of destruction of the competitive environment due to the bankruptcy of medium and small companies.

3) legislation. In logistics, legislation has a great influence both on the level of customs policy laws and on the entry and exit of goods [22].

Therefore, logistics enterprises constantly need development and improvement, as well as a detailed study of all possible influencing factors and an individual approach to each innovation. Science is constantly developing, new technical inventions appear, which are successfully implemented by logistics companies, which significantly simplifies the process of material and technical support of production and increases the efficiency of their activities

The use of innovations will contribute to the optimization of logistics flows, which will make it possible to obtain an economic effect and increase the competitiveness of not only logistics centers, but also partners in the market of goods and services.

Conclusions. Thus, the development of logistics in Ukraine has significant potential for further growth, thanks to the introduction of innovative technologies, infrastructure improvements and adaptation to new market conditions.

Consequently, with ever-increasing consumer expectations and a shift in interests towards product diversity and personalized services, pressure on logistics companies and supply chains is growing. Businesses are faced with a difficult choice of various new technologies, such as IoT, automated mobile robots, artificial intelligence, and blockchain solutions to invest in. As technological advances continue unabated, it is important for companies to identify potentially disruptive changes to the marketplace at an early stage...

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