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TRANSFORMATION OF FUNCTIONAL LOGISTICS UNDER THE INFLUENCE OF DIGITALIZATION

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Abstract. This article investigates the specifics of functional logistics transformation under the influence of the digitalization of the economy. It identifies key directions for implementing digital technologies in logistics processes and characterizes the functional areas of logistics. Furthermore, the paper synthesizes modern digital technologies utilized in the functioning of logistics systems, outlining their advantages and disadvantages. A study and generalization of modern digital technologies applied within the functional activities of logistics systems in the European Union countries have been conducted. The drivers of modern digitalization and their impact on Key Performance Indicators (KPIs) are systematized. Finally, the benefits of the digital transformation of functional logistics for enterprises are substantiated, and the primary risks associated with its implementation are identified.

Keywords: Digital transformation, digitalization, functional logistics, logistics, management.

Introduction. Digital technologies are developing rapidly in the global market, reshaping approaches to business process management and creating entirely new models of interaction between economic entities. Functional logistics is currently one of the largest domains undergoing profound digital shifts. Logistics management coordinates integrated flows across various supply chains, which demands rapid response to changes, adaptability, flexibility, and systemic flow control.

Digitalization is becoming a decisive factor in enhancing enterprise competitiveness, as it enables cost optimization, accelerates managerial decision-making, and ensures the transparency of logistics operations.

Traditional approaches to functional logistics management are no longer highly effective, given that the global economy is characterized by a high level of turbulence driven by geopolitical shifts, macroeconomic instability, and radical disruptions in global supply chains. Consequently, an objective need arises for a fundamental transformation of logistics management, with complete digitalization serving as the core catalyst.

In recent years, the evolution of digital logistics has progressed from the automation of individual logistics operations to the creation of innovative, intelligent, and autonomous ecosystems.

The relevance of studying this process is reinforced by the fact that functional logistics is no longer merely an operational component of enterprise activities; instead, it has become a critical strategic element of value chain management, ensuring the preservation of competitive advantages and business resilience under conditions of uncertainty.

For Ukraine, studying the transformation of functional logistics is of paramount importance. Under wartime conditions, enterprises are forced to operate in extreme environments and plan post-war recovery strategies amidst massive destruction of logistics infrastructure, shifts in traditional transport corridors, and severe human resource shortages. In this context, the integration of digital technologies becomes the sole mechanism to ensure flexibility and rapid real-time adaptation of logistics processes. Therefore, researching the transformation of functional logistics under the influence of digital technologies is of particular urgency and relevance.

Research Aim and Objectives.

The aim of this article is to provide a theoretical substantiation of the transformation process of functional logistics under the influence of modern digital technologies, identifying the key advantages and disadvantages of their application in managing enterprise flow processes.

To achieve this set aim, the study addressed the following objectives:

– synthesized theoretical approaches to defining the essence of "digital transformation of functional logistics";

– investigated the nature of changes in key functional areas of logistics;

– systematized modern digital technologies applicable across various functional areas of logistics;

– determined the advantages and disadvantages of digital technologies in terms of their utilization in flow process management;

– outlined the specific internal influences on digitalization.

Results and Discussion.

In modern economic literature, numerous studies are dedicated to the digital transformation of the economy, including logistics [1-6]. The digital transformation of logistics and supply chain management remains a focal point of attention for leading academic economists. Let us consider several of these perspectives.

The digital transformation of logistics processes – through the utilization of automated monitoring systems for material flow displacement, the application of predictive analytical demand models, and the integration of artificial intelligence algorithms into managerial decision-making – contributes to increasing order fulfillment accuracy, reducing logistics costs, and ensuring a higher level of operational efficiency of enterprises in a highly dynamic market environment [6].

While recent years have witnessed a major leap in the development of artificial intelligence and autonomous control systems, the theoretical works of scholars are

most often dedicated to the fragmented use of individual digital technologies in various areas of functional logistics. However, the contemporary understanding of digitalization is far deeper, encompassing all areas of logistics and integrating information and technology into a single digital space.

In scientific literature, the concept of "digital transformation" is viewed as a comprehensive process of integrating digital technologies into business models, organizational structures, and operational processes of an enterprise to create value and enhance its overall operational efficiency.

Currently, digital transformation in logistics systems is interpreted not merely as the automation of individual operations or the implementation of modern software, but as a new concept of managing material, information, financial, and service flows.

It should be emphasized that the digitalization of functional logistics entails a transition from the fragmented management of individual logistics functions to the creation of a unified digital environment where all supply chain participants interact in real time.

In functional logistics, digital transformation is regarded as a process of modernizing key logistics subsystems by implementing digital technologies that provide automation, integration, analytical support, and intelligent management of business processes. At the same time, the process of digital transformation encompasses not only technological changes but also all organizational, managerial, and personnel aspects of the enterprise's activities and the entire supply chain.

Based on the synthesis of existing scientific approaches, it is expedient to define the "digital transformation of functional logistics" as a comprehensive process of qualitative changes in the system of enterprise logistics function management, grounded in the integration of digital technologies, intelligent analytics, and automated information systems to increase the efficiency of logistics processes, the transparency of supply chains, and the adaptability of the enterprise to a dynamic market environment.

A distinctive feature of the digital transformation of functional logistics is its orientation toward creating a unified digital space within which continuous data exchange occurs among all entities of the logistics system. This approach ensures the agility of managerial decision-making, minimization of logistics risks, optimization of customer service levels, and the enhancement of the enterprise's competitive position.

The implementation of new technologies requires significant financial expenditures and highly qualified personnel, as well as the availability of infrastructure capable of supporting these technologies. Therefore, it is crucial for logistics companies to correctly choose strategies and technologies that yield the maximum effect at minimum cost [3].

The systemic integration of digital technologies into logistics infrastructure enhances coordination among suppliers, production units, and distribution structures, which ensures the timeliness of logistics operations, reduces the risk of material shortages, and increases the adaptability of enterprises to the dynamics of the external environment [1].

Functional logistics is a set of interrelated logistics functions aimed at ensuring effective management of material flows. The main functional subsystems of logistics include: procurement, production, transportation, warehousing, distribution, inventory, reverse, and information logistics.

Digitalization of logistics involves the integration of digital technologies into all logistics processes. The primary driving forces of digital transformation are: market globalization, e-commerce growth, the development of Industry 4.0 technologies, rising customer expectations, and the objective necessity of cost optimization.

The Logistics 4.0 concept entails using innovative digital technologies to automate and optimize logistics processes across all functional areas. This concept is based on the application of artificial intelligence, the Internet of Things (IoT), robotics, big data, and cloud platforms.

Research conducted in recent years indicates that digital transformation substantially increases the transparency, flexibility, integration, and adaptability of logistics systems.

The application of modern digital technologies helps enterprises of any level to increase efficiency and performance, reduce costs, and achieve a synergistic effect from logistics activities.

Modern digital technologies that are most effective in specific functional areas of logistics are presented in Table 1.

Table 1 Modern digital technologies by functional areas of logistics

FUNCTIONAL AREA OF LOGISTICS	DIGITAL TECHNOLOGIES
Procurement	E-procurement, cloud technologies, artificial intelligence (AI), blockchain
Production	Internet of Things (IoT), robotics and automated systems, 3D printing, augmented reality (AR) and virtual reality (VR), ERP platforms
Distribution	CRM systems, Internet of Things (IoT) / RFID, blockchain, omnichannel distribution models
Warehousing	WMS systems, robotics, automated guided vehicles (AGVs) / unmanned vehicles, automated systems, digital twins
Transportation	TMS systems, autonomous vehicles, artificial intelligence (AI), cloud technologies, machine learning, GPS
Customer Service	CRM systems, chatbots, mobile applications
Inventory Logistics	Big Data, predictive analytics, Internet of Things (IoT) / RFID
Reverse Logistics	Blockchain, cloud systems, Internet of Things (IoT)

In the domain of procurement logistics, digitalization enables the automation of supplier selection, demand forecasting, and real-time inventory management in purchasing. The application of big data analytics enhances forecasting accuracy and mitigates the risk of material resource shortages.

The digitalization of production logistics is closely associated with the deployment of cyber-physical systems, digital twins, and automated manufacturing complexes. By implementing these digital technologies, enterprises gain the ability to

dynamically plan production processes, minimize equipment downtime, perform predictive maintenance, and build production schedules.

The digitalization of transport logistics plays a crucial role. Using smart devices for cargo tracking provides real-time location data and allows for a rapid response to changing logistical situations. Digital transport systems facilitate route optimization, fuel cost reduction, enhanced transportation safety, minimized environmental footprint, and improved delivery timeliness.

The digitalization of warehouse logistics is realized through the "Smart Warehouse" concept. Implementing robotic solutions significantly reduces order processing times and enhances the precision of warehousing operations.

The rapid growth of e-commerce stimulates the digitalization of distribution processes. The key vectors of digital transformation in distribution logistics include automated order management, the use of digital platforms, the implementation of omnichannel distribution models, and the application of artificial intelligence for demand forecasting. Through these digital solutions, enterprises can respond more rapidly to customer needs and deliver high service levels.

The advantages and disadvantages of using modern digital technologies in functional logistics are synthesized in Table 2.

Table 2 Advantages and disadvantages of using modern digital technologies in functional logistics

Digital technologies	Advantages	Disadvantages
Artificial Intelligence (AI)	Enables supply chain self-organization; Analyzes market indicators; Automates routine processes; Forecasts demand and requirements; Evaluates supplier risks; Improves planning and forecasting accuracy.	Requires high-quality data; Involves high implementation costs; Carries risk of algorithmic errors; Demands extensive personnel training.
Blockchain	Ensures supply chain transparency; Simplifies document flow; Protects against counterfeits; Enhances trust among participants; Reduces fraud risks.	Involves high implementation costs; Presents integration complexity; Offers limited scalability; Shows low readiness among suppliers.
Internet of Things (IoT)	Enables automated inventory control; Provides real-time vehicle tracking; Ensures warehouse data accuracy; Reduces operational costs; Automates information exchange among supply chain participants.	Depends heavily on IT infrastructure; Exposes systems to cyber risks; Involves high hardware costs; Presents integration complexity.
Big Data	Provides in-depth data analysis; Forecasts market trends; Supports decision-making; Mitigates operational risks.	Requires highly skilled analysts; Suffers from data quality issues; Involves high system acquisition costs.

RPA (Robotic Process Automation)	Automates repetitive, manual tasks; Reduces human-error rates; Saves operational time.	Offers limited flexibility; Depends heavily on underlying IT systems; Requires continuous software updates.
Cloud Technologies	Ensures high data accessibility; Offers flexible scalability; Reduces local infrastructure costs; Enables easy system integration.	Carries cybersecurity and data risks; Depends on constant Internet connection; May cause service incompatibility issues.
3D Printing in Logistics	Reduces warehouse inventory and storage costs; Lowers transport costs via localized production; Increases order fulfillment speed and flexibility; Mitigates supply chain disruption risks.	Involves high equipment and material costs; Restricts product range and materials; Offers low efficiency for mass production; Requires highly specialized personnel.
Unmanned Delivery Vehicles	Accelerates "last-mile" delivery; Enables access to hard-to-reach areas; Reduces dependence on road infrastructure; Lowers long-term operational costs.	Limits payload capacity and range; Faces strict regulatory and legal restrictions; Demands high safety and security standards; Requires significant maintenance investments.
AR & VR for Logistics Process Modeling	Facilitates inventory control and system visualization; Allows risk-free testing of operational scenarios; Reduces system design and planning errors; Improves staff training efficiency.	Involves high initial investment costs; Depends heavily on input data quality; Offers limited integration with legacy IT systems; Requires specialized technical skills.
E-procurement	Ensures tender process transparency; Automates document and purchasing flows; Reduces corruption and compliance risks.	Requires extensive user training; Involves high system setup costs; Depends heavily on standardized protocols.
Robotic Systems	Increases productivity and operational speed; Minimizes the human-error factor; Ensures consistent process execution quality; Enables continuous 24/7 operations.	Requires high capital intensity for implementation; Presents integration complexity with existing flows; Involves significant maintenance costs; Carries social risks of job displacement.

EDI Systems	Accelerates commercial document exchange; Reduces transaction error rates; Ensures data consistency and compliance; Enhances logistics process transparency; Synchronizes partner activities; Elevates information security levels.	Requires substantial initial software investments; Involves personnel training costs; Faces difficulty adapting to non-standard processes; Offers limited flexibility compared to modern cloud and API solutions.
Green Technologies (Greentech)	Delivers long-term cost savings; Avoids carbon and environmental penalties; Grants access to "low-cost" investments and credits; Optimizes warehouse and resource utilization.	Requires high initial capital investments; Suffers from a lack of supportive infrastructure; Presents high technological complexity.

The business model of a logistics enterprise is characterized by the logical structure of its logistics system and the practical modeling of economic, analytical, graphical, and software substantiations. This structure aims to identify the most effective method for combining material, information, financial, and associated flows to optimize procurement, production, distribution, transportation, warehousing, and service business processes both within the logistics enterprise and beyond its boundaries [2].

Digitalization significantly impacts the transformation of logistics management within logistics systems, changing approaches to planning, organizing, controlling, and optimizing material, information, financial, and service flows. The implementation of digital technologies in functional logistics provides data-driven, integrated supply chain management in real time, which is crucial for complete and timely customer order fulfillment.

The implementation of digital technologies in the functional sphere of logistics is influenced by the following factors:

- the level of digital maturity and IT infrastructure;
- the organizational structure and management system of the enterprise;
- the corporate culture and strategic priorities of the leadership;
- human resource potential;
- the level of standardization and formalization of logistics processes;
- the financial capability of the enterprise.

To form a more detailed understanding of the processes and vectors of digital transformation, it is necessary to generalize the modern technologies utilized in the European Union countries, given that Ukraine is on the path toward European integration. An analysis of modern digital technologies utilized in the functional operations of logistics systems in EU countries, which are currently not fully implemented within the logistics systems of Ukraine, is synthesized in Table 3.

Table 3 Modern digital technologies utilized in the functional operations of EU logistics systems

Technology	Functional Capabilities	Current Status in Ukraine
Supply Chain Digital Twins	Create a complete virtual replica of the supply chain. The system dynamically calculates various scenarios and capabilities of logistics systems, individual supply chains, and logistics infrastructure in real time under various factors and constraints.	Isolated cases within global companies; lack of local infrastructure for such computations.
Scope 3 Carbon Accounting Platforms	Enable automated calculation of emissions based on fuel type, cargo weight, and route. This is a mandatory requirement for securing contracts with major EU retailers.	Virtually unused due to the absence of strict environmental penalties and reporting requirements.
Warehouse Execution Systems (WES)	Manage fully automated (dark) warehouses where AI dynamically adjusts warehouse management systems based on inventory turnover rates.	Only in the initial stages of implementation (e.g., specific sorting centers of Nova Poshta). The overall level of robotization remains low due to lower labor costs compared to the EU. In Ukraine, systems that guide human operators (e.g., Paperless/Voice Picking) are predominantly utilized.
Shared "Physical Internet" (PI) Platforms & Freight Uber 2.0	Apply the asset-sharing concept. These are not merely digital bulletin boards (like Lardi-Trans), but algorithmic systems that autonomously consolidate cargo from different companies into a single vehicle to maximize capacity utilization (pooling).	The market remains highly fragmented, dominated by direct "freight forwarder-carrier" interaction.
Blockchain Platforms for Customs Clearance and Freight	Enable automated release of payment to the carrier upon digital confirmation of cargo delivery, without accounting department intervention (using smart contracts).	Implementation is hindered by the lack of legislation on digital document exchange and general distrust toward decentralized systems.

The primary gap lies in the fact that Ukraine's logistics systems are currently undergoing the stage of operational automation, whereas EU systems have already reached the stage of autonomous management and environmental synchronization.

Table 4 summarizes digitalization factors, their impact on logistics management, and Key Performance Indicators (KPIs).

KPIs are utilized in logistics management to monitor logistics service levels, logistics costs, speed, and reliability of logistics operations. They are essential for managerial decision-making and for assessing the impact of digitalization on the efficiency of logistics systems.

Table 4 Digitalization factors and their impact on logistics management and KPIs

Digitalization Factors	Impact on Logistics Management and KPIs
Internet Mobility and Availability	Facilitates real-time operational management of logistics processes, improves transparency of transportation and warehousing, and reduces decision-making time.
Datafication	Enables data-driven logistics management, improves demand forecasting accuracy, optimizes inventory levels, and reduces logistics costs.
Computerization and Automation	Automates accounting, planning, and control of logistics operations, improving logistics personnel productivity.
Artificial Intelligence (AI) and Machine Learning	Optimizes routing, predicts supply chain disruptions, supports management decision-making, and improves logistics service levels.
Information Processing Speed	Shortens logistics cycles, reduces order lead times, and increases the flexibility of logistics systems.
Cloud Technologies	Integrates logistics processes among supply chain participants and reduces IT infrastructure costs.
Internet of Things (IoT)	Provides real-time monitoring of cargo movement and goods status, reduces losses, and increases delivery and service reliability.
Blockchain	Enhances trust among supply chain participants, ensures transparency of logistics operations, and reduces transaction risks and costs.
Digital Platforms and Marketplaces	Optimizes interaction with carriers and clients, reduces coordination costs, and increases the speed of information exchange among supply chain actors.
Robotic Logistics Processes	Increases warehouse logistics productivity, reduces operational costs, and decreases dependence on the human factor.
Cybersecurity	Ensures continuity of logistics processes and mitigates risks of data loss and supply chain failures.
Customer-Centricity and Personalization	Improves logistics service quality, increases customer satisfaction levels, and enhances performance KPIs.
Environmental Digitalization	Optimizes routes considering emissions and reduces the ecological footprint of logistics operations.
Human Resource Digital Transformation	Improves the efficiency of logistics management and strengthens the ability to work with analytical and digital systems.

The digitalisation of logistics chains represents a fundamental vector for the development of modern logistics, ensuring multicomponent optimisation of operational activities. The integration of information technologies into logistics processes contributes to enhancing supply chain adaptability, minimising transaction costs, and ensuring the structural flexibility of logistics systems in the long term [4].

One of the most significant results of the digital transformation of logistics is a substantial increase in the transparency of logistics processes. The integration of modern information systems, Internet of Things (IoT) technologies, cloud services, and other digital solutions into the management of logistics flows enables the acquisition of real-time data regarding cargo movement, inventory status, vehicle performance, and order fulfilment. This facilitates a reduction in uncertainty within logistics operations management, minimises the risk of disruptions, and increases the reliability of supply chain functioning.

Digitalisation also significantly transforms the processes of planning, organisation, and managerial decision-making within logistics systems. The utilisation of Big Data analysis and artificial intelligence technologies creates the prerequisites for more accurate demand forecasting, transport route optimisation, the determination of rational inventory levels, and the modelling of alternative scenarios for the development of logistics processes. As a result, logistics management transitions from a reactive to a proactive approach, gaining the ability not only to resolve current issues promptly but also to identify potential risks in advance and develop effective response mechanisms.

An important area of digital technology influence on the functional spheres of logistics is the automation of operational activities. The implementation of automated systems for warehouse management, transport operations, and procurement allows for the reduction of manual labour, the minimisation of errors, and the enhancement of operational productivity. Furthermore, the robotisation of warehouse processes and the use of autonomous vehicles contribute to reducing operational costs, accelerating order processing, and increasing the overall efficiency of logistics activities.

The nature of interaction between supply chain participants is also undergoing significant changes. Through the implementation of electronic data interchange (EDI), digital platforms, and integrated information systems, continuous coordination of activities between suppliers, carriers, logistics operators, and end consumers is ensured. This approach allows for the reduction of transaction costs, increases the consistency of managerial decisions, and facilitates the formation of modern network models for logistics process management.

At the same time, digitalisation creates new opportunities for increasing the level of customer-centricity in logistics systems. The use of digital communication channels and consumer behaviour analysis tools enables a more precise consideration of individual customer needs, the personalisation of logistics services, and the provision of a high level of service. This contributes to meeting established delivery parameters, improving the quality of logistics service, and strengthening long-term customer relationships.

In the context of the digital economy, logistics management is increasingly based on the use of digital competencies, effective data management, and the application of intelligent decision-support systems. Consequently, digital transformation serves not only as a tool for the optimisation of individual logistics operations but also as a foundation for forming a new model of logistics system functioning, oriented towards innovation, customer-centricity, environmental responsibility, and the principles of sustainable development.

The efficiency of implementing digital transformations in logistics systems is largely determined by the level of digital maturity of enterprises, the availability of qualified personnel, the financial capabilities of business entities, the quality of regulatory support, and the degree of digital infrastructure development. For Ukrainian enterprises, issues regarding the integration of modern digital technologies into logistics processes, ensuring cybersecurity, developing digital personnel skills, and

adapting logistics systems to the influence of external factors and crisis phenomena in global supply chains are of particular importance.

The future development of functional logistics will be associated with the implementation of autonomous logistics systems, digital twins, and intelligent supply chain management platforms.

Conclusions.

In the context of modern transformational processes, the digitalisation of functional logistics acts as one of the key factors for enhancing the efficiency, flexibility, and resilience of enterprises. Its implementation ensures the ability of enterprises to adapt promptly to changes in the market environment, increasing competitive pressure, and rising consumer demands, which is a necessary prerequisite for the successful functioning of logistics management within the global digital economy.

Digitalisation is a key priority for the transformation of an enterprise's functional logistics under the implementation of Industry 4.0 technologies, which ensures the improvement of logistics process efficiency, the enhancement of managerial decision-making quality, and the strengthening of the competitiveness of both enterprises and supply chains as a whole.

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