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Contents

INTRODUCTION

We are happy to invite you to get acquainted with the first issue of the new scientific and practical publication "Intellectualization of Logistics and Supply Chain Management".

We strongly believe that the launch of this magazine indicates the objective need to rethink a wide range of issues related to the development of theory and practice in logistics and supply chain management, awareness of the need to unite the scientific community and logistics practitioners, dissemination of modern knowledge and best practices for innovative development of the logistics services market.

The first issue of the magazine is published at a difficult time. The global coronavirus pandemic and the deep economic crisis have significantly worsened business activity in the world. Currently, global supply chains are collapsing, international trade is declining, and competition between global and regional logistics operators is intensifying. The most common thesis is that the world will never be the same again. Industry experts predict the emergence of new, more flexible and adaptive supply chain management strategies and approaches to logistics business process management. The trend towards collaborations, cooperation and unification of services is emerging, comprehensive proposals for clients are being developed. There is increasing talk about the need to build bimodal supply chains, which involves the development of different decision-making scenarios: the traditional approach - cost-effective efficiency, low risk, high predictability; a new approach "second mode" - rapid recognition of opportunities, adaptability, willingness to solve unexpected problems and look for new opportunities.

Radical transformations of the global and national markets for logistics services require appropriate scientific support. Logistics science has a special role to play in this process. Initiating the emergence of a new journal, we decided to focus on its coverage of problematic aspects of the formation and development of logistics systems at the micro, mezo and macro levels, supply chain management, digitization of logistics, methods and tools for optimizing processes in logistics and supply chains, sociopsychology relations and network interaction of enterprises using cloud technologies, artificial intelligence, e-learning, neural business process management systems, etc.

Therefore, we invite scientists, researchers and business representatives, as well as our colleagues from abroad, to cooperate and present the results of scientific research, to discus and debate on them, to work together to develop the scientific theory of logistics and promote mutual intellectual enrichment.

We hope that the new scientific publication will become a theoretical guide for young researchers and representatives of other fields.

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A LOGISTICS-DRIVEN APPROACH TO ENSURING THE COMPETITIVENESS OF UKRAINIAN BUSINESS TOURISM

Olga Karpun, Valeria Yakovenko. "A logistics-driven approach to ensuring the competitiveness of Ukrainian business tourism". *The article examines the essence of the process of organizing business trips involving air transport, which is a key component of business tourism. It is noted that this process requires a systematic logistics-driven approach to enhance the competitiveness of companies in this industry.*

It was noted that, in our opinion, a logistics-driven approach to ensuring the competitiveness of business tourism lies in the implementation of the supply chain management concept, which aims at effectively serving demand and creating added value for consumers, as well as realizing a customer-centric approach in managing the activities of companies in the tourism industry.

It was also emphasized that a logistics-driven approach to ensuring the competitiveness of business tourism can be implemented at various stages of organizing business trips, thereby contributing to the achievement of overall optimization of the customer service chain. Therefore, the process of organizing business trips involving air transport was analyzed in detail, problem areas were identified at each considered stage, and solutions were proposed.

Given the high level of competition and the rapid change in market conditions, companies need to apply a logistics-driven approach to optimize business processes, enhance the efficiency of customer interaction, and improve the transportation component.

The main directions for using a logistics-driven approach to enhance the competitiveness of companies in the tourism industry were identified as the optimization of routine and time-consuming processes. It was noted that the automation of these processes using CRM systems, robotic parsers, and artificial intelligence will significantly reduce the time spent on processing requests, as well as increase the speed and accuracy of decision-making. Furthermore, the implementation of IP telephony and integrated communication channels will ensure continuous monitoring of customer interactions, which will improve the overall level of service.

Thus, the use of a logistics-driven approach to ensuring the competitiveness of business tourism will significantly increase the efficiency of resource management, reduce costs, improve the quality of customer service, and ensure flexibility in responding to market changes.

***Keywords**:* logistics-driven approach, competitiveness, business tourism, business travel, air transport, business trips organization process, business trips optimization

Ольга Карпунь, Валерія Яковенко. «Логістичний підхід до забезпечення конкурентоспроможності українського бізнес-туризму». *У статті розглянуто сутність процесу організації бізнес-подорожей за участю авіатранспорту, який є ключовою складовою ділового туризму. Зазначено, що даний процес потребує системного логістичного підходу для підвищення конкурентоспроможності компаній у цій галузі.*

Було зазначено, що на нашу думку, логістичний підхід до забезпечення конкурентоспроможності бізнес-туризму полягає у втіленні концепції управління ланцюгами поставок, що має на меті ефективне обслуговування попиту і створення додаткової цінності для споживачів, а також реалізує клієнтоорієнтований підхід в управлінні діяльністю компаній туристичної галузі.

Також було наголошено, що логістичний підхід до забезпечення конкурентоспроможності бізнес-туризму можна впроваджувати на різних етапах організації бізнес-подорожей, сприяючи тим самим досягненню загальної оптимізації ланцюга обслуговування клієнтів. Саме тому, було детально проаналізовано процес організації бізнес-подорожей за участю авіатранспорту, визначені проблемні місця на кожному розглянутому етапі та запропоновані рішення.

Враховуючи високий рівень конкуренції та швидку зміну ринкових умов, компаніям необхідно застосовувати логістичний підхід для оптимізації бізнес-процесів, підвищення ефективності взаємодії з клієнтами та вдосконалення транспортної складової.

Основними напрямами використання логістичного підходу для підвищення конкурентоспроможності компаній туристичної галузі були визначені оптимізація рутинних та часозатратних процесів. Було зазначено, що автоматизація цих процесів за допомогою CRM-систем, роботизованих парсерів та штучного інтелекту дозволить значно скоротити витрати часу на обробку запитів, а також підвищити швидкість і точність прийняття рішень. А впровадження IP-телефонії та інтегрованих каналів комунікації забезпечить безперервний контроль за взаємодією з клієнтами, що підвищить загальний рівень сервісу.

Таким чином, використання логістичного підходу до забезпечення конкурентоспроможності бізнес-туризму дозволить суттєво підвищити ефективність управління ресурсами, знизити витрати, покращити якість обслуговування клієнтів та забезпечити гнучкість у реагуванні на зміни ринку.

Ключові слова: логістичний підхід, конкурентоспроможність, бізнес-туризм, бізнес-подорожі, авіатранспорт, процес організації бізнес-подорожей, оптимізація бізнес-подорожей

Introduction. The development of business tourism is acquiring particular significance in the context of Ukraine's economic transformation, its European integration course, and post-crisis recovery. Business tourism acts as a powerful driver for the activation of international business interaction, the stimulation of investment, job creation, and GDP growth. At the same time, current challenges, particularly the closure of Ukrainian airspace, the destabilization of transport and logistics infrastructure, and the reorientation towards international hubs, have significantly complicated the organization of business trips.

The situation is further complicated by increasing competition in the tourism services market, rising customer demands for the quality, speed, and personalization of service. In such circumstances, business tourism enterprises require new approaches to ensure their competitiveness. A logistics-driven approach, based on systematic flow management, process digitalization, and customer focus, is considered an effective tool for achieving this goal.

Problem statement (formulation of research purposes). Based on the conducted analysis of scientific literature, it was found that many researchers consider logistics as a tool for enhancing company competitiveness [3, 5, 6]. They note that "the development of logistics is primarily driven by the desire to reduce time and monetary costs associated with the movement of goods" [6]. Furthermore, "based on the logistics approach to competitiveness management, new sources of competitive advantages for the enterprise are created, which are based on low costs" [3].

It should also be noted that there is a growing interest in the application of logistics in the tourism industry [7, 12, 13, 14]. In particular, work [13] states that "the logistics approach contributes to the sustainable development of the tourism industry through the efficient use of resources, enables governing bodies to monitor the market situation, implement innovative technologies, and utilize feedback from customers." In another source, we find the assertion that "currently, traditional logistics prevails in the tourism sector of Ukraine, where many operators have only begun to form their first electronic logistics structures" [7].

However, we can argue that a comprehensive model for applying the logistics-driven approach specifically in the field of business tourism under the conditions of the transformation of Ukraine's transport system and the growth of digital competition has not yet been sufficiently developed. Therefore, it is necessary to pay attention specifically to the study of the general principles of logistics management in business tourism, the role of digital technologies in customer service logistics, and methods for improving the efficiency of business travel logistics chains.

The purpose of the article is the theoretical substantiation and development of practical recommendations for enhancing the competitiveness of business tourism based on a logistics-driven approach.

To achieve this purpose, the following tasks are set in the article:

– to investigate the specifics of logistical business processes in the field of business tourism;

– to analyze current trends influencing the competitiveness of tourism enterprises;

– to identify logistical tools that contribute to improving the efficiency of customer service;

– to propose logistical solutions for optimizing the activities of tourism companies in new market conditions.

The main material and results of the research. The organization of business trips involving air transport is a key component of business tourism, requiring a systematic logistics-driven approach to enhance the competitiveness of companies in this industry.

We note that, in our opinion, a logistics-driven approach to ensuring the competitiveness of business tourism lies in the implementation of the supply chain management concept, which aims at effectively serving demand and creating added value for consumers, as well as realizing a customer-centric approach in managing the activities of companies in the tourism industry [based on 4]. The logistics-driven approach, as an innovative model of development and management, can be considered an important condition for achieving the sustainable competitiveness of Ukrainian business tourism.

A logistics-driven approach to ensuring the competitiveness of business tourism can be implemented at various stages of

organizing business trips, thereby contributing to the achievement of overall optimization of the customer service chain.

The process of organizing business trips involving air transport includes several important stages, the main ones of which are presented in Fig. 1. Initially, it is necessary to analyze the client's needs, determine the purpose of the trip, budget, and deadlines. Next, the optimal route and carriers need to be selected, followed by booking airline tickets through global distribution systems (GDS) or directly through airlines. The subsequent step is the organization of related services, such as hotels, transfers, and conference rooms, as well as registration of insurance policies and visa support. The final stage involves monitoring the trip and promptly adjusting the itinerary in case of changes.

We can assert that the competitiveness of companies in the field of business tourism largely depends on effective customer acquisition channels. The main ways to find clients currently include participation in tender procurements through platforms such as SmartTender, Prozorro, and Zakupivli.pro, as well as direct contacts, both warm and cold. Additionally, promotion through social networks, particularly Facebook and LinkedIn, is actively used, allowing for faster identification of potential clients and maintaining communication with regular partners.

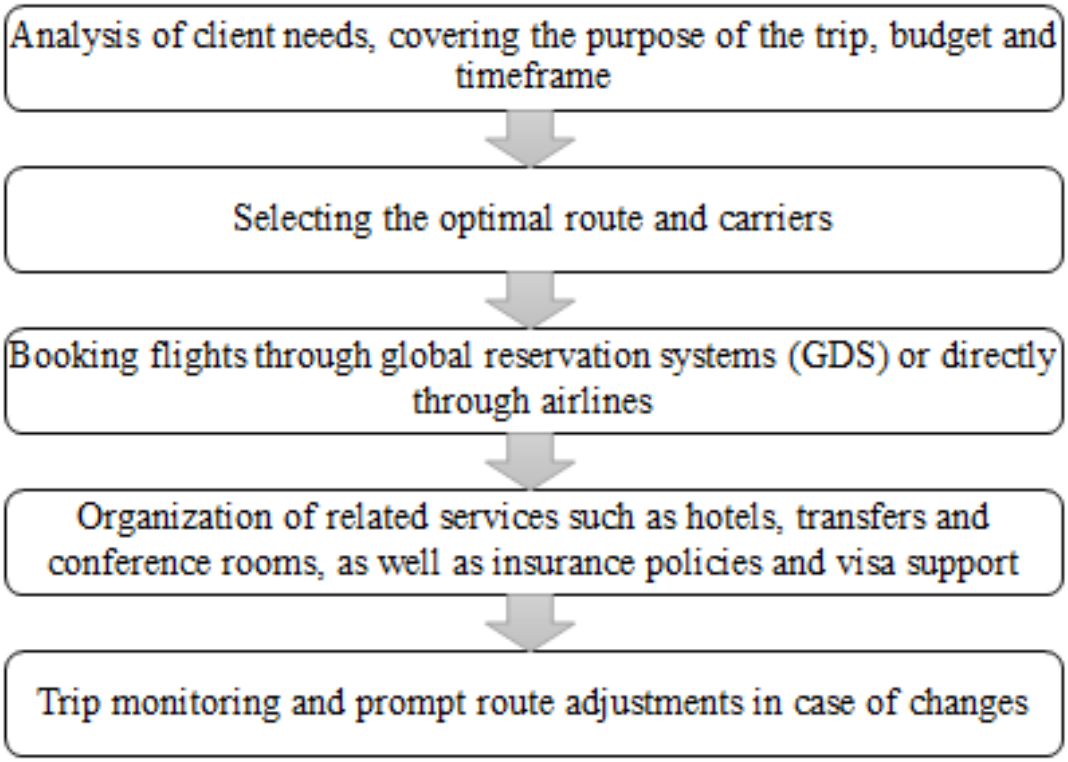

Figure 1 – The process of organizing business trips involving air transport

During the full-scale invasion of Ukraine, the structure and routes of air transportation underwent significant changes. The main departure points for Ukrainian business tourists shifted to European hubs. Experts in the business tourism industry note that Warsaw has become the most popular departure city, accounting for approximately 70% of flights, while 20% of flights originate from Chisinau, and the remaining 10% from other European cities such as Budapest and Vienna. The majority of travel requests (around 70%) concern European destinations, which is explained by convenient connections and affordable ticket prices.

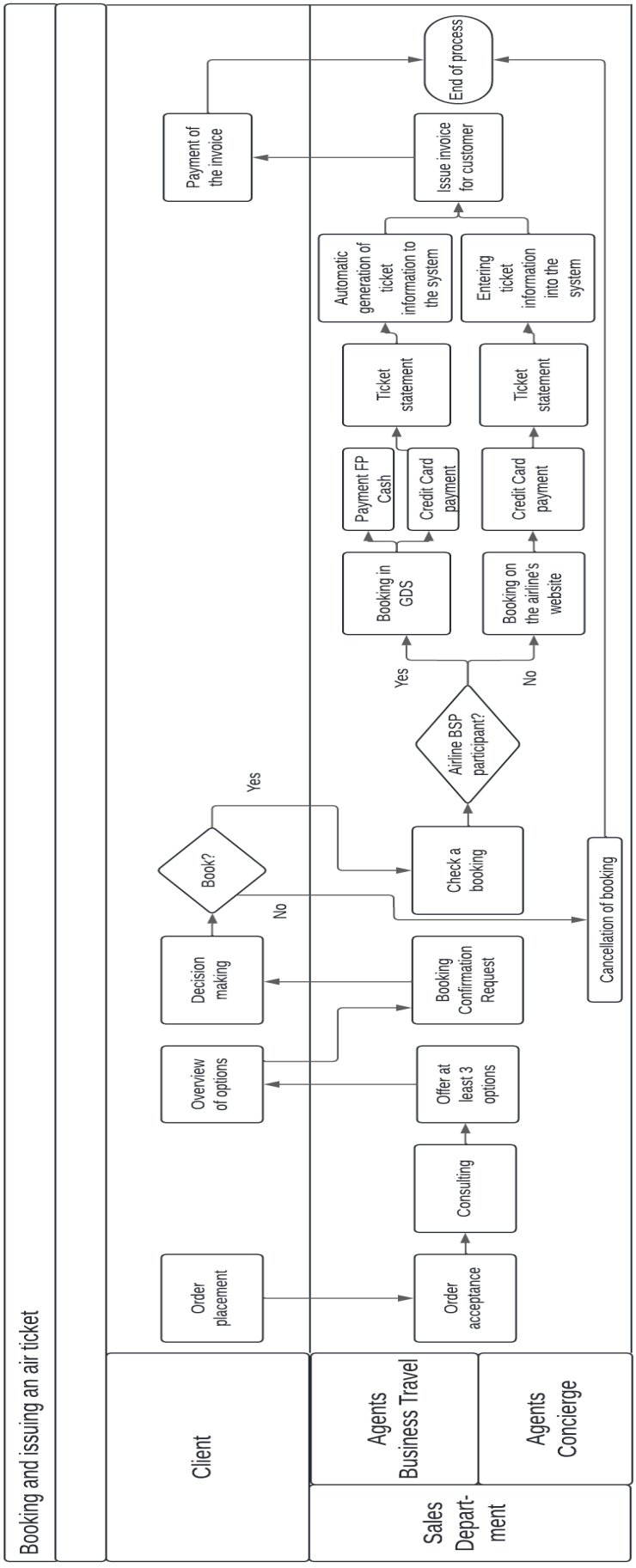

Figure 2 – Business process chain for booking and issuing an airline

At the same time, air travel within Europe accounts for approximately 60% of the industry's revenue due to the significantly higher cost of flights to the USA and Asia.

To ensure high-quality service for business tourists, travel companies actively interact with airlines, transport companies, hotels, transfer companies, and conference centers. Cooperation with many tourism service providers (airlines, transport companies, hotels, transfer companies, conference centers, etc.) allows for finding the optimal option that meets the client's requirements and capabilities, and sometimes even exceeds their expectations. Accreditation from IATA (International Air Transport Association) is a significant competitive advantage, as it allows for making bookings through GDS, working with a wide range of air carriers, receiving special conditions from airlines, and increasing customer trust.

The choice of airline for a business trip depends on the route, budget, and level of comfort. The most popular air carriers for business tourists currently include Turkish Airlines, Lufthansa, Air France KLM, and LOT Polish Airlines [11]. The selection of a specific carrier is often determined by the client's needs, which may include the necessity of connections, the level of comfort during the flight, or other additional requirements.

A typical business process for organizing air transportation (Fig. 2) begins with the client placing an order, which can be done via email, messengers, or phone. Next, consultation on flight options takes place, after which the client is offered several alternatives with different connections, airlines, and schedules. After selecting the optimal option, a booking is made in the system, for example, through Amadeus or another GDS. The next stage is determining the payment method, which can be via financial transfer or credit card. After this, an electronic ticket is issued and sent to the client, and at the final stage, an invoice for the services provided is generated.

For the effective operation of companies in the business tourism industry, various information support systems are used. These include booking systems such as Amadeus, TravelPoint, and Galileo, which allow for efficient handling of tickets and routing. In addition, specialized databases for the visa department are used, simplifying document processing, as well as access to confidential airline fares. The use of online booking, Google services, and specialized modules for hotel reservations enables the provision of comprehensive service to clients.

In the field of business travel organization, the BSP (Billing and Settlement Plan) system plays an important role, consolidating information and cash flows between agents and airlines. BSP is a central point through which data and funds flow between travel agents and airlines [1]. Instead of each agent having individual relationships with each airline, all information is consolidated through BSP. It allows for a single payment covering sales for all airlines, ensuring a high level of timely settlements. In addition, BSP provides reporting and settlement obligations (RHC) for making payments, which increases the financial efficiency of companies in the business tourism sector.

The main advantages of BSP are presented in Fig. 3.

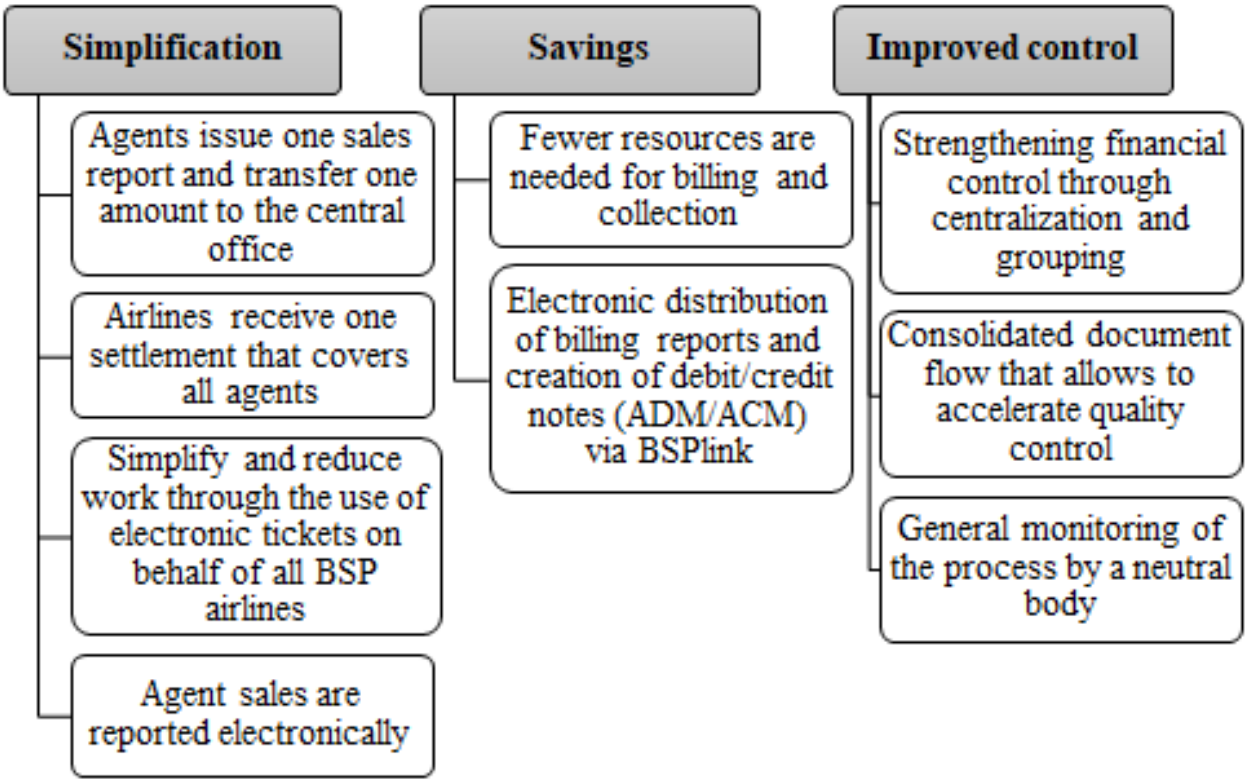

Figure 3 – Benefits of using Billing and Settlement Plan (BSP)
Source: compiled by the authors based on [1]

In the process of organizing business trips involving air transport, companies face both opportunities and threats that affect the competitiveness of the entire sector. A SWOT analysis of the business tourism industry allows for the assessment of these aspects and the identification of strategic directions for development.

The strengths of companies operating in the field of business tourism include a customer-oriented approach, which encompasses 24/7 customer support, high labor productivity, team cohesion, and a developed corporate culture. Important competitive advantages are participation in international business associations and a developed partnership system with key players in the logistics chain, including airlines, hotels, and transport carriers.

However, the industry also has weaknesses, among which is complex multi-channel communication with clients, involving phone calls, messages in messengers, and email. This complicates the speed of processing requests and can lead to the loss of some information during the transfer of a client to another agent. Irregular working hours, requiring availability on weekends, as well as agent burnout, create additional challenges for companies.

The development of technology opens up significant opportunities for improving business processes in the field of business tourism. The use of cryptocurrencies in settlements can simplify payments and minimize dependence on banking restrictions. The integration of NDC (New Distribution Capability) content allows for access to more favorable fares and special offers from airlines [2].

Despite the prospects for development, the business tourism industry faces serious threats. The reluctance of some airlines to work with Ukrainian agents limits the possibilities for booking airline tickets and obtaining exclusive fares. Strict banking regulation of international operations creates additional difficulties in conducting business, especially when making payments abroad.

The technological aspect remains another bottleneck for the industry. Despite the widespread use of booking systems and a management system, the lack of full integration between them leads to duplication of information, manual data entry, and increased risks of errors. The absence of an automated process for generating personalized offers based on customer interaction history limits the possibilities for improving service and operational efficiency. In addition, insufficient integration between marketing and logistics processes complicates effective demand and resource management.

Given the high level of competition and the rapid change in market conditions, companies need to apply a logistics-driven approach to optimize business processes, enhance the efficiency of customer interaction, and improve the transportation component.

Recommendations for enhancing the competitiveness of business tourism based on a logistics-driven approach are based on a comprehensive analysis of existing processes and the search for ways to optimize them.

The main directions for using a logistics-driven approach to enhance the competitiveness of companies in the tourism industry are the optimization of routine and time-consuming processes.

The automation of these processes using CRM systems, robotic parsers, and artificial intelligence will significantly reduce the time spent on processing requests, as well as increase the speed and accuracy of decision-making. The implementation of IP telephony and integrated communication channels will ensure continuous monitoring of customer interactions, which will improve the level of service.

Particular attention should be paid to the transportation component of the industry. The high volatility of airline, railway, and road transportation can cause delays and additional costs for business tourists. The application of demand forecasting algorithms and route optimization will allow companies to proactively book the most advantageous transportation options, minimizing delays and inefficient expenses. In addition, the implementation of blockchain technologies in the booking system will improve the transparency of operations, speed up payment confirmations, and reduce the likelihood of fraudulent schemes.

Communication with customers involves the use of all interaction channels. Therefore, one way to increase competitiveness is the implementation of a unified communication system. Such systems allow for the automation of the process of designing various services for different clients, which not only saves time and effort at the management level but also increases the accuracy of data collection on each client, their preferences, and requirements [15].

An example of such a system is KeyCRM – a Ukrainian CRM for built-in integration with Instagram, Viber, Telegram, Facebook, and Email. As a communication platform, KeyCRM:

– gathers all requests from all accounts in a single window.

– allows for processing correspondence without leaving the dashboard: conducting dialogues, processing applications, creating Customer cards, sending any files: photos and images, videos, emojis, and communicating via voice messages.

– displays overall statistics on chats: their number per week, day, month; average response speed. Detailed statistics are available in the form of diagrams and tables and can be filtered by periods.

– creates a truly user-friendly interaction system thanks to its ability to "recognize" a person and store important notes: birthday, preferences, etc. [10].

The activities of employees when booking in GDS involve providing several options for the client. Information from the global distribution system must be presented to the client in an understandable form. To optimize this process, the use of the Aviato.me service, which is free, can be proposed. The workflow with the proposed service is shown in Fig. 4.

A significant problem for the solution of which a logistics-driven approach can be used is the manual entry of information for some bookings into management accounting systems, which requires additional time. The need for manual input exists for booking tickets of low-cost airlines such as Wizz Air, Ryanair, easyJet, etc. A low-cost airline is an airline that provides air passenger transportation services at prices relatively lower than traditional airlines, in exchange for waiving most traditional passenger services.

The solution to minimize this "bottleneck" is the implementation of RPA (Robotic Process Automation). RPA is the robotization of routine processes. The main stages of the operation of such a parsing robot are shown in Fig. 5.

Robotic systems will be used to automate the processes of booking airline tickets. The use of robotic systems will reduce the amount of time and errors, which, in turn, increases safety and reduces the risks of problems [4, 8].

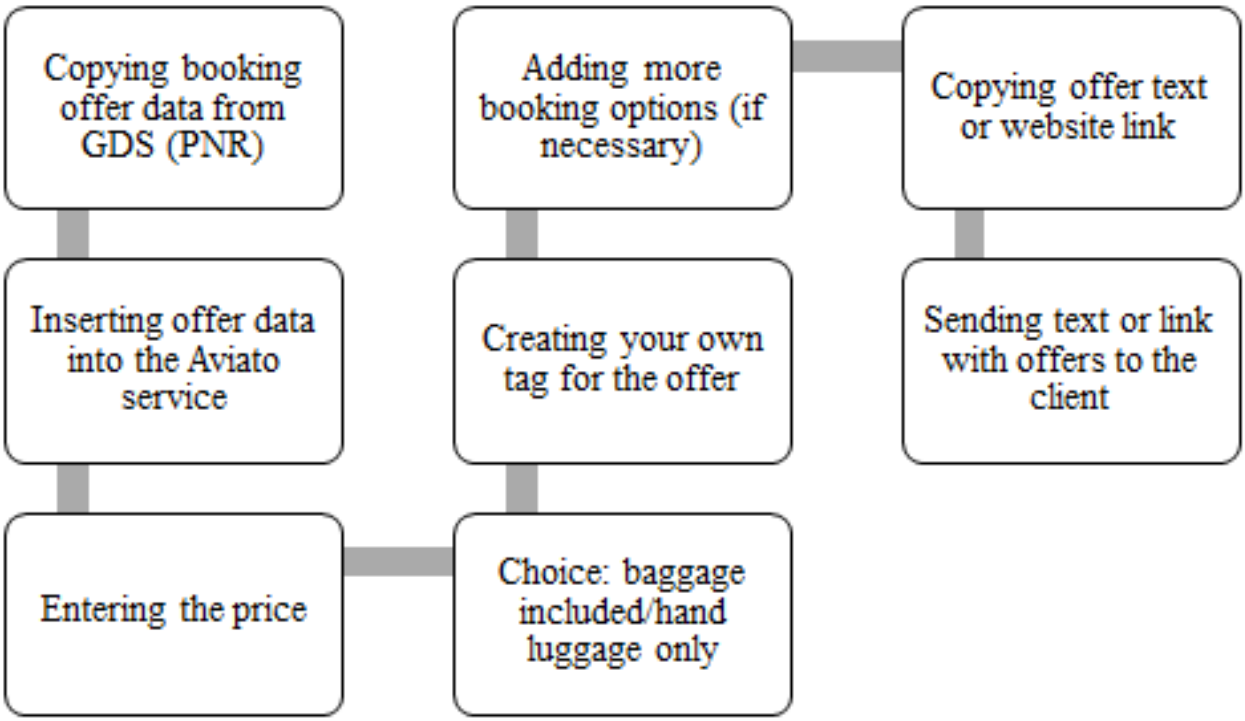

Figure 4 – Stages of optimizing the presentation of offers from GDS to the client

When the robot receives an email with an airline ticket, with the help of correctly configured algorithms, the main data from the ticket is transferred to a fixed data structure. After that, the integration of structured information into the management system will take place. The robot must be configured for different airlines, as each of them formats airline tickets differently.

For the development of companies in the tourism industry, the use of artificial intelligence (AI) is necessary. There are many types and areas of AI application. The use of artificial intelligence reduces the number of human errors and increases the efficiency of logistics processes, which ensures safety and reduces the risks of problems [4].

The logistics-driven approach in this case involves optimizing the search for airline tickets using AI Copilot from DRCT. DRCT strives to improve the distribution process for airlines and customize ticket sales for agencies. AI Copilot is designed to optimize and customize the booking and post-booking process.

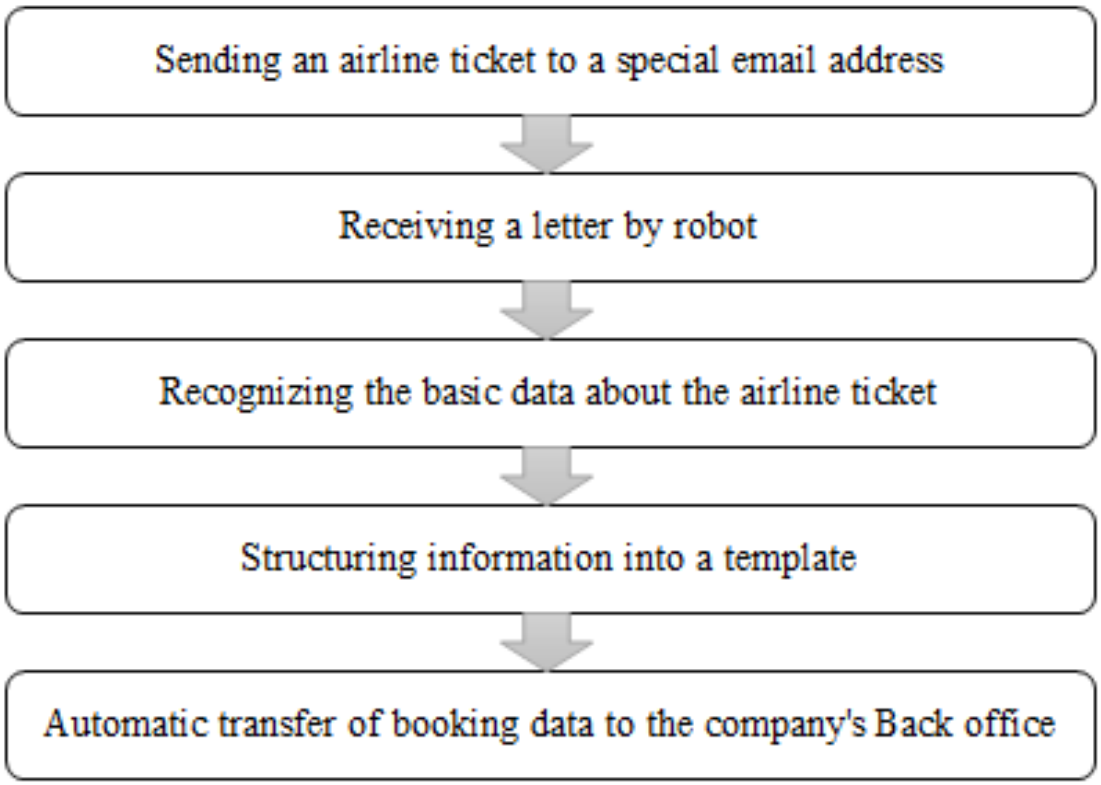

Figure 5 – Scheme of automating the entry of booking information into the management system using RPA

Artificial intelligence uses large language models, machine learning, and the experience of developers in this field to provide significant industry value. Fig. 6 shows an example of the AI Copilot's response to a user's service request. Instead of the usual interface, which includes dozens of filters for complex queries, conversational search reduces it to just a couple of lines of text. This AI can be used both online and in the application on any device. A feature of this service is the submission of a request in free form.

AI will reduce the time spent searching for favorable offers for clients according to the specifics of their requests [9].

The DRCT application allows you to search for flights and create bookings via NDC without leaving the GDS. NDC (New Distribution Capability) is a data exchange format based on offer and order management processes for creating and distributing relevant offers to customers regardless of the distribution channel. The NDC standard expands communication capabilities between airlines and travel agents and is open for implementation and use by any third party, intermediary, IT provider, or non-IATA member [2]. NDC allows data to be transmitted directly from air carriers to agents, bypassing intermediaries such as GDS. It provides access to the full content of the airline – fares and additional services.

DRCT has also created an application that enables the optimization of the activities of companies in the tourism industry when booking in the global distribution system.

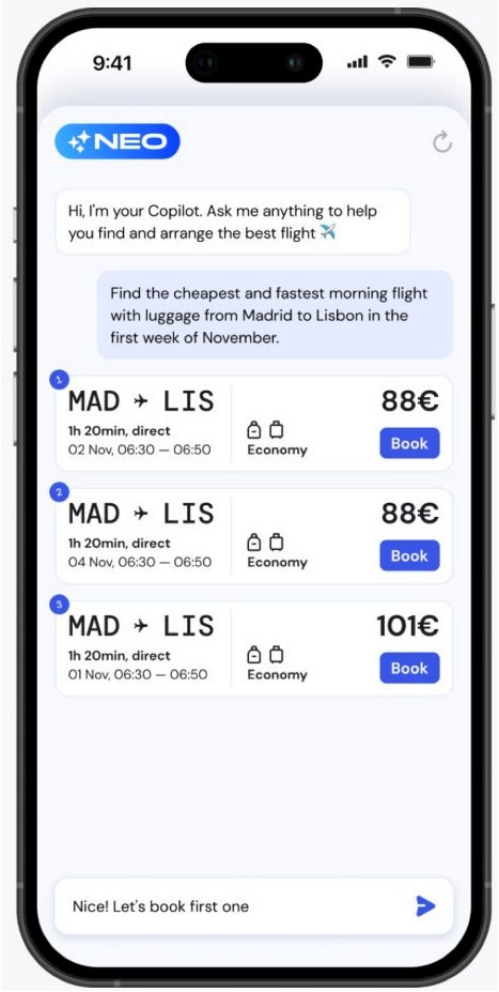

Figure 6 – Example of using AI Copilot from DRCT [4]

Currently, the following are available for booking: Aegean Airlines, airBaltic, American Airlines, British Airways, Brussels Airlines, Emirates, flydubai, Iberia, LOT, Lufthansa, SWISS, TAP, United Airlines, and more than 30 other airlines.

The service provides full access to booking: the booking itself, entering additional data without leaving the GDS. The agent is also provided with information on flight delays. The service allows for the exchange, refund, or issuance of tickets independently or through 24/7 support. Current agreements with airlines are used, and payments are made through BSP.

Thus, the implementation of a logistics-driven approach in the management of air transport enterprises and business tourism enterprises, as an innovative model of development and management is a key condition for achieving their sustainable competitiveness in the market [4]. The use of a logistics-driven approach significantly increases the efficiency of resource management, reduces costs, improves the quality of customer service, and ensures flexibility in responding to market changes.

Conclusions. The organization of business trips involving air transport constitutes one of the key components of the business tourism system and requires comprehensive logistical support to achieve high competitiveness of enterprises in the industry. In the context of the transformation of the international transport environment caused by hostilities in Ukraine, there is a reorientation of routes to European air hubs, which necessitates the adaptation of business models of tourism companies to new spatial and logistical conditions.

Promising opportunities for the development of the industry have been

identified, including technological integration with global distribution systems, the introduction of new payment formats, and the automation of operations.

A logistics-driven approach, focused on the effective management of information, material, and financial flows, creates opportunities for optimizing the operational activities of tourism companies. The use of CRM systems (in particular KeyCRM) contributes to the centralization and standardization of customer interaction, the use of GDS-based tools (Aviato.me) allows for improving the presentation of offers, and the implementation of RPA solutions automates routine tasks of processing booking data. The integration of intelligent systems such as AI Copilot provides more flexible booking management via NDC and significantly expands access to airline content.

As a result of the formation of a logistics-oriented business model, not only is the level of service improved, but the competitive positions of tour operators in a turbulent environment are also strengthened. The logistics-driven approach acts not only as a tool for improving internal business processes but also as a factor of strategic adaptability and long-term viability of companies in the business tourism industry.

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CONCEPTUAL APPROACH TO FINANCIAL SECURITY MANAGEMENT OF A LOGISTICS COMPANY

Oksana Pozniak, Maryna Yashchuk, Iryna Suvorova. "Conceptual approach to financial security management of a logistics company". *This article is devoted to researching and forming a conceptual approach to managing financial security in a logistics company, addressing the challenges of maintaining financial stability in a highly dynamic and risk-prone industry in the face of global challenges. The study reveals that financial security can be examined through multiple theoretical perspectives, each highlighting specific aspects but often lacking an integrated understanding. The article defines financial security as a state of balance between a company's financial resources and its short- and long-term objectives, its adaptability to financial challenges, and resilience to external and internal destabilizing factors. Based on this, a comprehensive concept of financial security management in a logistics company is proposed. The strategic foundations, key actors, goals, and tasks that form an integrated financial security system have been identified. It is described as a set of interrelated elements and mechanisms that ensure operational stability in the face of real and potential threats, risks, and global challenges. The core objective of such a system is to provide financial stability and enable timely and adequate responses to potential crises. The scientific novelty lies in developing a multi-dimensional model for assessing financial security, which incorporates financial metrics, the impact of human resources, sustainable development parameters, and global risk factors in the context of sustainable development. Particular emphasis is placed on sustainable finance, defined as the redirection of financial flows, such as*

investments, loans, and credit lines, towards projects and companies that advance environmental, social, and governance (ESG) goals. This includes areas such as climate change mitigation, energy efficiency, biodiversity preservation, and equitable social progress. The study substantiates that implementing a financial security management system allows for the creation of a qualitatively new and integrated safety framework with increased efficiency.

***Keywords**:* financial security, logistics company, conceptual approach, sustainable financing, ESG, financial stability, financial security indicators, global challenges

Оксана Позняк, Маріна Ящук, Ірина Суворова. "Концептуальний підхід до управління фінансовою безпекою логістичної компанії". *Стаття присвячена дослідженню та формуванню концептуального підходу до управління фінансовою безпекою в логістичній компанії, вирішуючи проблеми підтримки фінансової стабільності високодинамічної та схильної до ризиків галузі в умовах глобальних викликів. Дослідження показує, що фінансову безпеку можна розглядати з точки зору кількох теоретичних перспектив, кожна з яких висвітлює конкретні аспекти, але часто не має цілісного розуміння. У статті фінансова безпека визначається як стан балансу між фінансовими ресурсами компанії та її короткостроковими та довгостроковими цілями, її адаптивність до фінансових викликів та стійкість до зовнішніх та внутрішніх дестабілізуючих факторів. На основі цього запропоновано комплексну концепцію управління фінансовою безпекою в логістичній компанії. Визначено стратегічні основи, ключових учасників, цілі та завдання, що формують інтегровану систему фінансової безпеки. Вона описується як сукупність взаємопов'язаних елементів та механізмів, що забезпечують операційну стабільність перед обличчям реальних та потенційних загроз, ризиків та глобальних викликів. Основною метою такої системи є забезпечення фінансової стабільності та забезпечення своєчасного та адекватного реагування на потенційні кризи. Наукова новизна полягає в розробці багатовимірної моделі оцінки фінансової безпеки, яка враховує фінансові показники, вплив людських ресурсів, параметрів сталого розвитку та глобальних факторів впливу ризиків в контексті сталого розвитку. Особливий акцент робиться на сталому фінансуванні, яке визначається як реорієнтація фінансових потоків, таких як інвестиції, позики та кредитні лінії, на проекти та компанії, що сприяють досягненню екологічних, соціальних та управлінських (ESG) цілей. Це включає такі сфери, як пом'якшення наслідків зміни клімату, енергоефективність, збереження біорізноманіття та справедливий соціальний прогрес. У дослідженні обґрунтовано, що впровадження системи управління фінансовою безпекою дозволяє створити якісно нову та інтегровану систему безпеки з підвищеною ефективністю*

Ключові слова: фінансова безпека, логістична компанія, концептуальний підхід, стале фінансування, ESG, фінансова стабільність, індикатори фінансової безпеки, глобальні виклики

Introduction. The global economy is increasingly facing unpredictable challenges such as pandemics, armed conflicts, economic instability, inflationary fluctuations, environmental problems and rapid technological changes. Logistics companies, as key participants in global supply chains, are particularly vulnerable to such changes, which highlights the importance of effectively managing their financial security as a key tool for adaptation, stability and development. The logistics sector is critical to the stable operation of many industries, but at the same time it is sensitive to economic fluctuations. Rising fuel prices, currency instability, supply risks and disruptions in supply chains create additional financial burdens on the activities of these companies.

Financial security is an important element of the operational activities of logistics companies, as it allows to reduce financial losses, predict possible risks and respond to crisis situations in a timely manner. In

addition, in the context of the rapid development of digital technologies and increasing demands for the speed and efficiency of logistics processes, competent management of financial resources allows companies to invest in infrastructure modernization and new technologies without exceeding permissible financial burdens. Thus, the development of an effective financial security management system is a key condition for maintaining the competitiveness of logistics companies in the modern world, which makes this problem extremely relevant.

Analysis of recent research and publications. The literature review shows that approaches to the formation of the concept of "financial security" have been formed relatively recently, although Maslow defined security as one of the basic human needs. The development of economic relations and the growth of the role of finance in the activities of business entities have led to the understanding that certain aspects of security are formed in the process of managing their production, economic, and financial activities. Taking this into account, the following approaches to the definition of the concept of "financial security of an enterprise" have been formed, which are summarized in Table 1.

According to the approaches considered in Table 1, it can be noted that the key features of this concept are the following features:

1) ensuring a balanced and stable financial position;

2) promoting the effective operation of the enterprise;

3) allows to identify problem areas in the company's activities at an early stage;

4) neutralizes the crisis and prevents bankruptcy;

5) creates a sense of security for the enterprise from the destructive influence of external and internal threats;

6) forms the optimal level of stability and development potential of the enterprise.

Table 1 – Approaches to defining the essence of the concept of "financial security of the enterprise

№	The name of the approach	Scientists who support this approach	Definition of a concept that corresponds to a certain approach
1	2	3	4
1	Financial security is considered as a component of the economic security of an enterprise with appropriate management tools	S. F. Pokropivnyi, O. I. Sudakova, I. V. Bagrovetska, L. S. Kozak, K. S. Horyacheva, I. V. Chibisova, A. S. Krutova, T. O. Staverska, I. L. Shevchuk	"Financial security is an important component of the economic security of the enterprise, which is based on the "independence, efficiency and competitiveness of the enterprise's finances, which is reflected through a system of criteria and indicators of its condition, which characterize the balance of finances, sufficient liquidity of assets and the availability of necessary cash reserves, financial stability, degree protection of financial interests at all levels of financial relations" [7].
2	Financial security is considered as an independent object of management, the ability of an enterprise to effectively use its resource potential	O. V. Arefieva, T. B. Kuzenko, E. K. Bondarenko, O. S. Zhuravka, A. V. Gukova, I. D. Anikina, A. O. Yepifanov, V. I. Muntiyan, Y. B. Krakos, R. S. Papekhin	"Financial security is considered as the ability of a business entity to carry out its economic, in particular, financial activities, effectively and stably by using a set of interconnected diagnostic, instrumental and control measures of a financial nature, which should optimize the use of financial resources, ensure their proper level and level impact of risks" [9].

End of table 1

1	2	3	4
3	Financial security as a state (of resources, activities, financial interests, security, etc.) characterized by appropriate resistance to external and internal threats	I. O. Blank, O. I. Baranovskyi, O. I. Vorobyova, O. M. Marchenko, O. E. Ponomarenko, I. V. Nartova and I. O. Kirichenko, I. I. Mulyk, I. V. Nartova and Ya. O. Kirichenko and others.	"Financial security of a business entity is a generalization of the state of finances of the relevant business entity as of a specified date, which indicates the financial capabilities and ability to fulfill obligations and function effectively in conditions of instability, uncertainty and various financial and economic risks" [2].
4	Financial security as a risk management activity	O. A. Kyrychenko, I. V. Kudrya, V. I. Kutsyk, A. I. Bartysh and others	"Financial security of an enterprise is defined as the activity of risk management and protection of the interests of the enterprise from external and internal threats in order to ensure the stable development of the enterprise and the growth of its own capital in the current and strategic perspective" [4].
5	Financial security as a process (the process of ensuring the stability of its functioning, financial balance; the process of achieving a certain state, etc.)	O. V. Susidenko, K. S. Polovneva, L. O. Matviychuk and others	"Financial security is a purposeful multi-level process that includes a set of methods, resources, levers to ensure the protection of the financial interests of the business entity from the destructive influence of external and internal financial threats and the formation of the balance of the enterprise in the current and strategic perspectives under the conditions of a competitive environment" [8]
6	Financial security as a system (provision of financial resources; balanced state of elements and subsystems)	Yu. V. Lavrova, Zh. V. Kudrytska	"Financial security of an enterprise is a system that ensures the stability of important financial proportions of the enterprise's development, which form the security of its financial interests in balance with the financial interests of its economic agents" [5].
7	Financial security as a basis for the formation of investment attractiveness at the micro and macro levels.	Larysa Dokiienko, Nataliya Hrynyuk, Nataliia Babiak, Viktoriia Chepka	"Financial security of the enterprise is determined by an integrated set of components and factors that determine the main aspects of its financial independence and operational efficiency. Taking into account the complex impact of all factors determines the relevance of further improvement of approaches to assessing the enterprise's financial security as a basis for forming its investment attractiveness. The basis of assessing the enterprise's financial security level should be the definition of interdependence and mutual influence of its main components on the scale "level – state – position – zone" as a foundation for the formation of national investment attractiveness at the macro and macro levels" [1].

Source: developed by the authors based on [1-9]

Summarizing the above, it is worth noting that each of these approaches nevertheless focuses attention on certain essential aspects, without forming a holistic view. Each researcher adds their own clarifications to the existing characteristics of financial security, because the category of finance is also multifaceted and synthesized, but the common idea that emerges from all definitions is this: maintaining an enterprise in a state of financial security is the main prerequisite for its stable development Therefore, the main goal of ensuring the financial security of the enterprise is to guarantee its stable current activity and high development potential in the future.

Objectives statement. The article aims to develop a conceptual approach to managing the financial security of a logistics company based on system-oriented management by ensuring a timely response to risks through preventive or reactive anti-crisis management that determines financial stability and resilience.

Basic material and results. Financial security is the state of a logistics company that ensures the balance of financial resources between the company's needs for the realization of short-term and long-term goals, the ability to adapt to financial stability and resistance to the negative impact of external and internal threats and destabilizing factors. This provides potential economic development of the logistics system and requires a detailed consideration of the constituent elements of the above definition.

First, this definition combines the balance between the formation of financial resources, which are limited and are formed from various sources of capital, with the interests and needs of the logistics company. The capital structure, the interdependence between own and borrowed financial resources, determines financial stability and solvency, forming the logistics company's financial independence from external entities.

Secondly, the definition combines the formation of financial resources by achieving long-term and short-term goals, which defines the tasks and goals of financial security by time periods and levels of management (strategic and tactical).

Thirdly, the logistics company must constantly adapt its financial security strategy to the challenges of the global environment, by identifying and evaluating the impact factors of threats to ensure that the impact of identified challenges on the financial security of the logistics company is minimized.

Fourth, financial stability, financial balance and financial flexibility are decisive for maintaining financial security and ensuring the development potential of a logistics company.

In accordance with the proposed definition of the concept of "financial security of a logistics company", the strategy, subjects of financial security, purpose and tasks that form the comprehensive concept of financial security of a logistics company shown in Fig. 1 are defined.

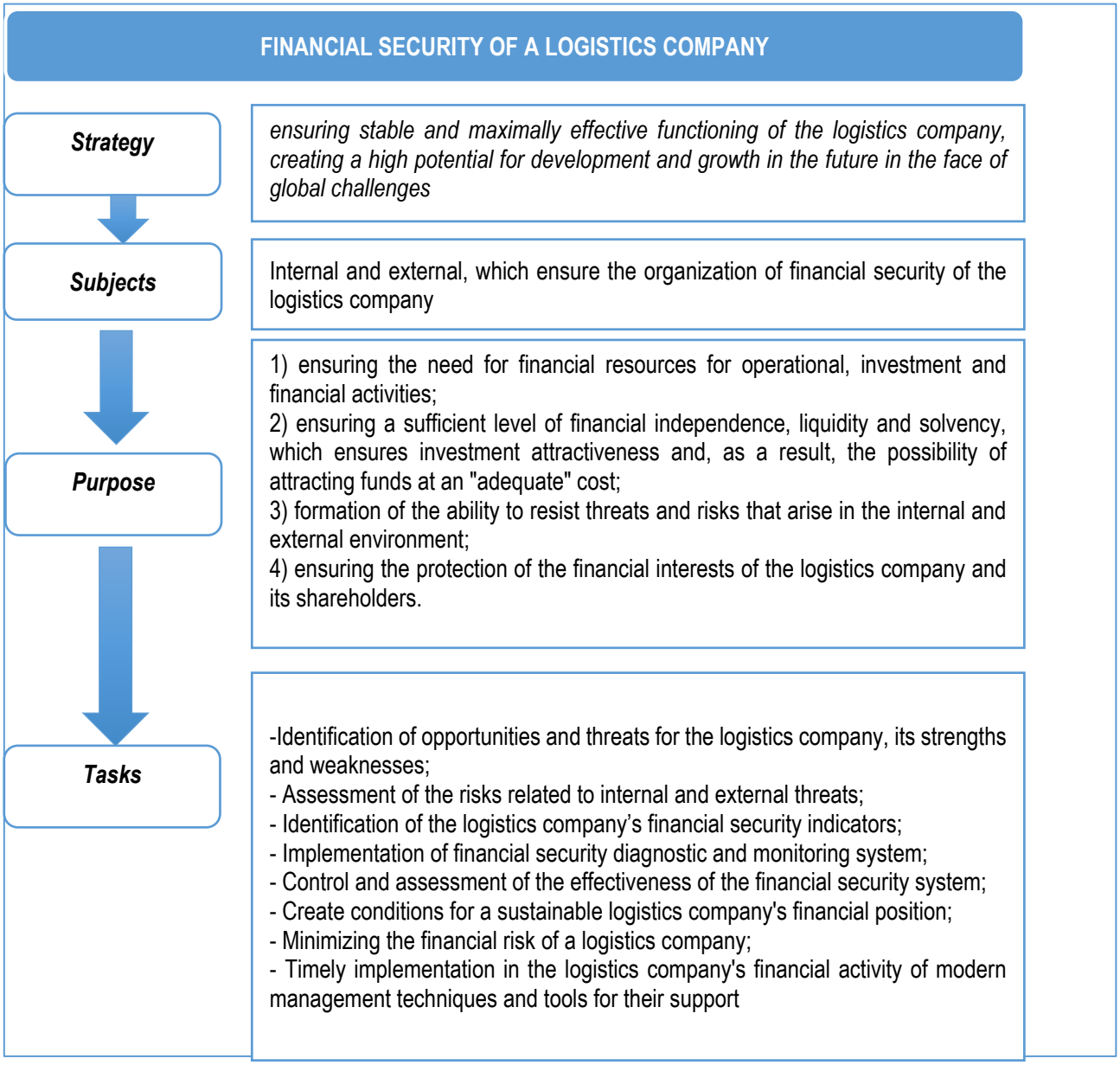

Figure 1 – The process of organizing business trips involving air transport
Source: developed by the author based on [6]

The proposed comprehensive approach to defining the concept of financial security of a logistics company provides an opportunity to form a system for ensuring the financial security of a logistics company, which is shown in Fig. 2.

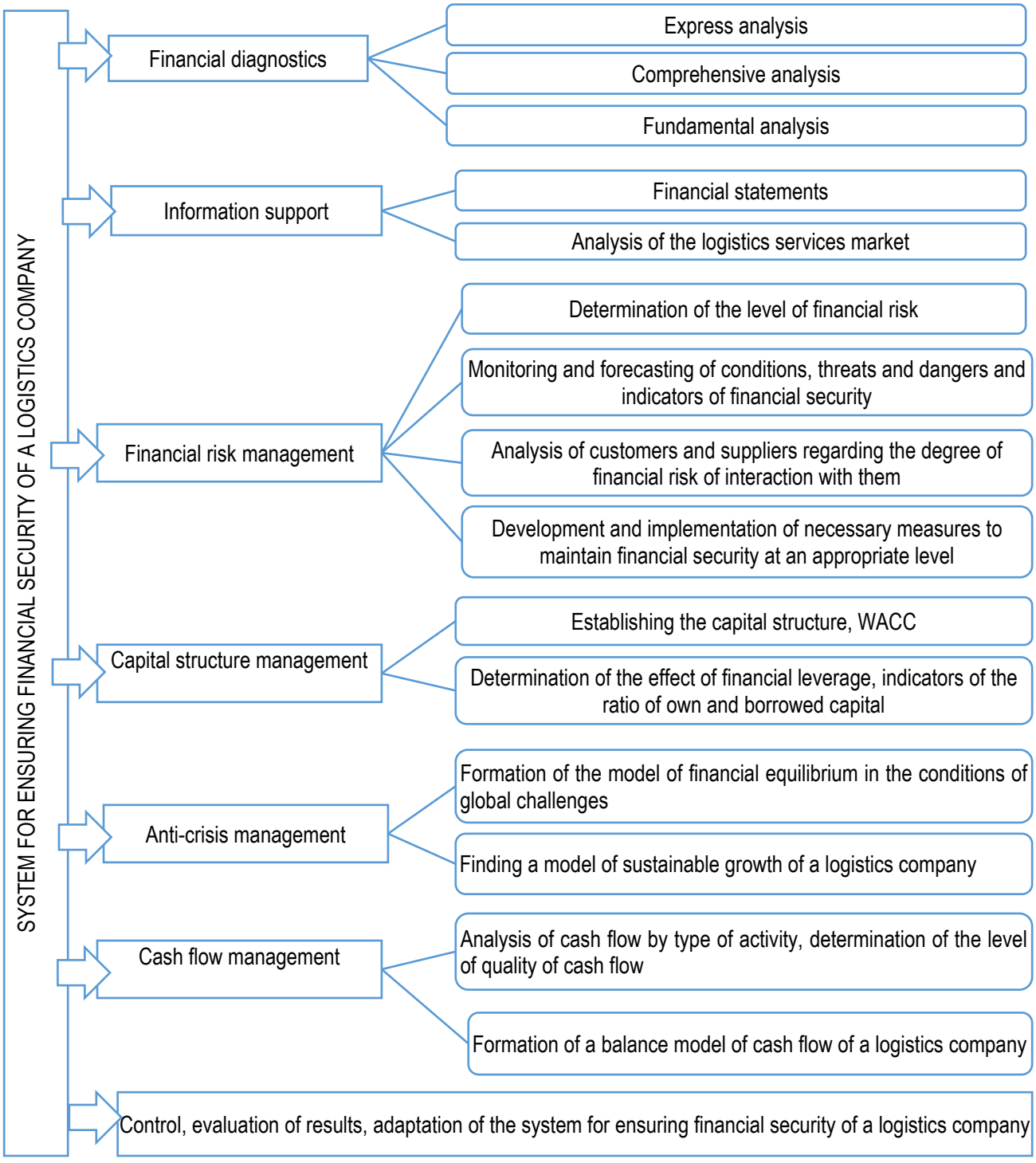

Figure 2 – System for ensuring financial security of a logistics company
Source: developed by the author

The first subsystem is the financial diagnostics subsystem. Financial diagnostics is a method of learning the financial mechanism of an enterprise, the processes of formation, and the use of financial resources for its operational and investment activities. Diagnostics allows in the early stages to determine the onset of a crisis situation, to assess the level of threats to the efficient operation of the logistics company and the factors that caused them. Therefore, the main purpose of this system is to assess the degree of threat and timely inform about possible

problem areas in the company's work. The main tasks facing diagnostics are:

- timely determination of the logistics company's crisis environment and outline of the main critical risks;
- assessment of the probability of a crisis and the possibility of bankruptcy;
- analysis of both the external and internal environment in which the logistics company operates;
- based on the conducted analysis, identification of weak points in the activities of the business entity;
- assessment of the efficiency of the logistics company.

The subsystem of financial diagnostics forms the basis for carrying out a multi-level set of diagnostic measures, monitoring the internal environment of the logistics company, and its ability to withstand the challenges of the external environment and adapt to them. Financial security can be characterized using a set of quantitative and qualitative parameters of the financial state, which reflect the level of its protection against external and internal threats. At the same time, it is worth analyzing not only the financial condition of the logistics company but also all the main operational business processes that affect the activities of the logistics company as a whole.

Financial diagnostics includes the following levels of diagnostics, namely [2]:

1. Express diagnostics – the first level of financial diagnostics, which provides the possibility of a quick analysis. Such diagnostics help to identify signs of financial problems and the development of a crisis state of a logistics company at an early stage. In the process of express diagnostics, the financial condition and financial stability of the enterprise are analyzed using methods of financial analysis.

When carrying out this diagnosis, the recommended and actual value of each indicator is compared, while an assessment is made depending on the value limits for each criterion, which are set by the logistics company. Depending on the value of the indicator and the limits set for it, the indicator is evaluated with points from 0 to 10. If the overall score exceeds the dangerous level, then it is necessary to carry out comprehensive diagnostics to determine the reasons for the development of the crisis state, as well as specific "bottlenecks" in the activities of the logistics company.

2. Comprehensive analysis determines the next level of financial diagnostics, which includes both quantitative and qualitative analysis methods and allows for assessment of the real degree of threat and the financial condition of the logistics company. The use of qualitative analysis, based on the principle of quantitative express diagnostics, based on an extended test questionnaire with a significantly larger number of evaluation criteria, helps to see a more complete picture of the crisis and assess the level of threat to the financial security of the logistics company.

3. Fundamental diagnostics is the most complete level of complex financial diagnostics, which provides an opportunity to conduct an analysis, taking into account the stage of the logistics company's life cycle, and critical risks using the maximum diagnostic tools.

For the financial diagnostics subsystem to provide adequate data for making managerial decisions in the field of financial security, the initial data must be relevant, therefore, increased requirements are put forward for information support. It consists of current financial reporting and a report on the sustainable development of the logistics company and information on the state of the logistics services market, and should also include quantitative and qualitative values of financial security indicators, the presence of probable risks or threats, the formed financial interests of the company and the state of their implementation, a strategic plan ensuring financial security, the parameters of the use of financial resources and sources of their income. It is on this basis that all studies of the efficiency of the logistics company are conducted.

Also, an important element of the financial security system is the risk management subsystem, which includes the elimination or prevention of risk by assessing the financial condition of both customers and partners of the logistics company to reduce the adverse impact of certain factors on the results of operations, transfer of risk through its insurance and risk management.

The influence of the capital structure on financial security was already mentioned above, in this subsystem special attention should be paid to the determination of the weighted average price of capital, the determination of the capital structure depending on the business model of the logistics company, as well as the inclusion of capital structure indicators in financial diagnostics to assess the impact of this factor on the financial security.

The anti-crisis management subsystem defines models of financial security depending on the life cycle and global challenges facing the logistics company as a basis for sustainable development.

The cash flow management subsystem provides an opportunity to calculate not only the impact of cash flows from operating, investment, and financial activities but also to calculate free cash flow, which acts as a "financial security cushion" of a logistics company.

The last subsystem consists of three components - control, evaluation of results, and adaptation of the system according to challenges.

Control - provides an opportunity to compare the achieved results with the expected indicators and determine the degree of their deviation, determine the causes of deviations to significantly increase the effectiveness of the logistics company's financial security system. The main function of the subsystem of control and evaluation of results is the analysis and evaluation of the results of the activity of the system to ensure the financial security of the logistics company as a whole and the efficiency of the activity of each of its components. The result of this assessment is the formation of conclusions. To implement this function, it is necessary to monitor the implementation of the plan, conduct a deviation analysis, and make adequate corrections. This will help to identify areas of effectiveness or, conversely, inefficiency of the logistics company's financial security system. It is important not only to establish the cause of the deviation but also to take corrective measures to solve the problem. Accordingly, the subsystem of control and assessment of results ensures the relationship between the formation of an information base, planning, diagnostics, and control, unites the entire system, effectively coordinates it, and evaluates the effectiveness of its performance of tasks.

Thus, summarizing the consideration of the concept of financial security of a logistics company, it should be noted that it is a sufficiently complex integrated system that forms the basis for economic growth and sustainable development, in which conditions are created for the implementation of a financial mechanism capable of adapting to changing conditions in the internal and external environments, factors affecting the financial security of the logistics company. Therefore, in the context of ensuring financial security, it is necessary to identify these factors.

The formation of a unique system of financial security is an important element for the stable functioning and development of a logistics company. The system should include the following main components: financial diagnostics, information support, financial risk management, a subsystem of financial instruments and security levers, as well as mechanisms for monitoring and evaluating results. Regular implementation of these measures contributes to improving the overall efficiency of the enterprise, increasing productivity, optimizing costs, restructuring assets and liabilities, as well as improving the marketing strategy. In the event of a crisis, the management must make timely decisions that take into account the specific causes and factors of the development of crisis processes.

The financial security system of a logistics company can be defined as a set of interconnected elements and mechanisms that ensure the stability of its activities, taking into account the impact of existing and potential risks, global challenges, threats, and dangers. System-oriented management in this context creates an opportunity to achieve the company's strategic and current goals. The main goal of creating a comprehensive system of financial security is to ensure the financial stability of the logistics company and its ability to respond in a timely and adequate manner to real and possible risks. A comprehensive system of financial security has the task of maintaining the stability of the company and management in crisis conditions through preventive or reactive anti-crisis management. When creating and operating a financial security system, it is necessary to take into account key aspects: the principles of building an enterprise, its organizational and management structure, the effectiveness of the functioning of divisions, as well as the financial security management system.

The security management system of a logistics company is a set of interconnected elements, each of which makes a unique contribution to the system, which gives it specific properties as a whole. All components of the system are interconnected and interact with each other, forming a qualitatively new integrated security system with an increased level of efficiency, which is shown in Fig. 3.

The object of the logistics company's financial security system is its assets, financial resources, capital, information resources, personnel, non-property rights and economic interests, as well as indicators reflecting financial stability, solvency and profitability, which indicate the level of financial security of the company. Thus, management covers the protection of the financial, property, technological, personnel, information and intellectual potential of the logistics company.

The main strategy of financial security of the logistics company was defined in fig. 1. As part of its implementation, the following strategies are defined, namely:

1. Risk reduction strategy: involves the diversification of suppliers, customers and sources of financing, which allows to reduce the logistics company's dependence on certain market segments.

2. Liquidity preservation strategy: maintaining a sufficient level of liquid assets that will ensure the fulfillment of short-term obligations.

3. Investment strategy: aimed at effective asset management in order to preserve and increase the financial resources of the logistics company.

4. Anti-crisis strategy: includes action plans in case of financial crises, allowing to quickly adapt to adverse economic conditions.

In addition, the logistics company's financial security management system should be based on the following principles, which are shown in Fig. 4.

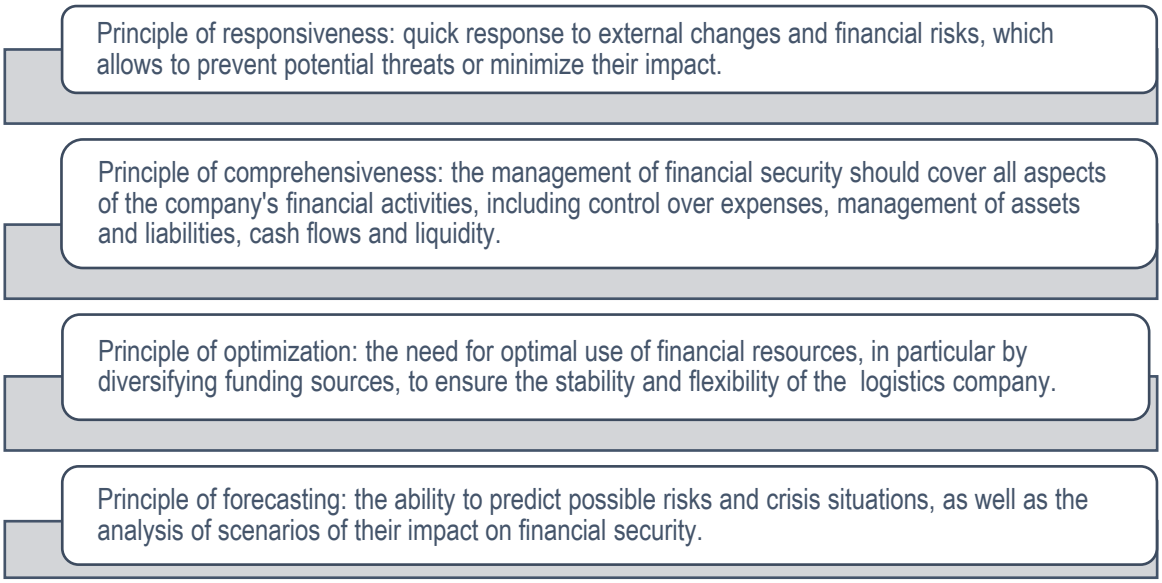

Figure 4. Principles of managing financial security of a logistics company

The next block of the system is represented by the main components, which include:

An information and analytical system that determines the collection and analysis of financial information necessary for risk assessment, forecasting and decision-making. It includes regular monitoring of financial indicators and external factors that may affect security. The information and analytical system is based on reliable external and internal data. External data includes information about economic conditions, market trends, regulatory changes and competitive factors that affect financial stability. Internal data includes the company's financial performance, cash flows, expenses, and the structure of assets and liabilities of a logistics company. Information about the risks of currency fluctuations, credit risk, operational risks, etc. deserves special attention.

The organizational structure of financial security management is determined by internal and external entities involved in the management of various aspects of financial security: financial analysts, risk managers, accountants, as well as defining their roles and responsibilities.

Control and audit mechanisms provide for regular internal and external audits of financial indicators and processes to identify and correct possible shortcomings and risks of the logistics company.

If the first two blocks of the system form a categorical and organizational apparatus, then the next block - the financial security management mechanism - is the core of this system, and defines the process of ensuring financial security as the actions and interactions of the elements of the mechanism and management structure.

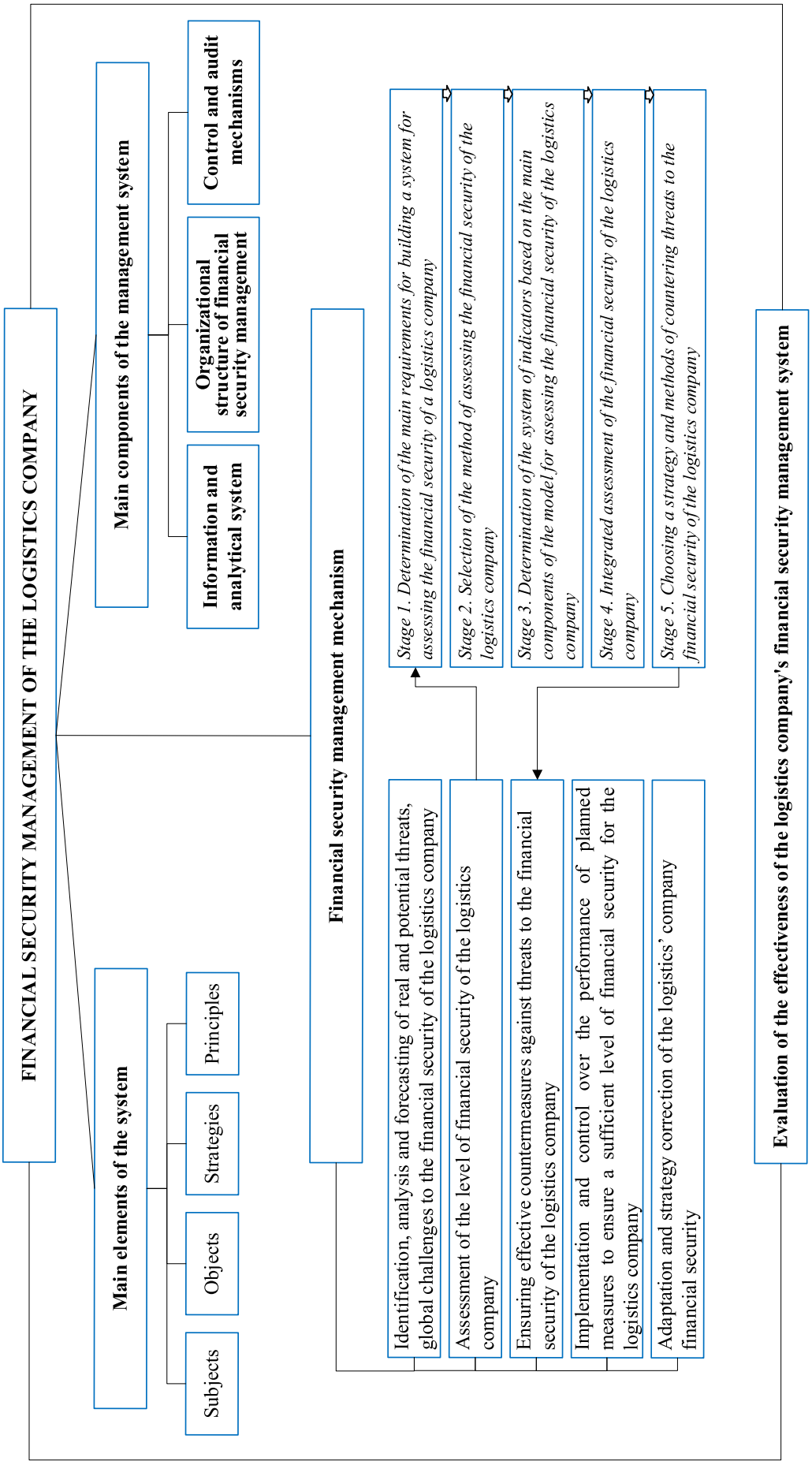

Figure 3. Conceptual model of managing the financial security of a logistics company

Source: developed by the author

In the first stage, the types and causes of negative impacts on the logistics company that threaten its financial security are determined. These negative effects can be both subjective and objective. Subjective factors include internal and external actions resulting from conscious decisions (or inaction) of people and other market subjects that may harm the enterprise, as well as the consequences of poor-quality work by employees or partners. Threats, risks, and global challenges facing the logistics company were identified in the theoretical chapter of the qualification work. Of course, a logistics company can identify threats and risks that are personalized, that is, they affect a specific logistics company.

One of the main elements of the mechanism is the system for assessing the level of financial security of the logistics company. The logistics company can choose equal models for evaluation. It is proposed to expand this stage and consider in more detail the algorithm for assessing the financial security of a logistics company.

The main requirements for building a system for assessing the financial security of a logistics company include, firstly, comprehensiveness, which determines that the system should cover all the main aspects of the logistics company's financial activities, including the management of assets, income, expenses, liquidity, investment activities, and credit obligations. The assessment should take into account both internal and external factors affecting financial security.

Second, objectivity and accuracy, which means that up-to-date financial indicators, statistical data, and relevant financial reports must be used to ensure the reliability of the data. The evaluation system should be based on objective methods of analysis that exclude subjective evaluation.

Thirdly, operational efficiency is characterized by the fact that the system should allow rapid detection of negative changes and risks, as well as provide the possibility of rapid adjustment of financial security protection strategies.

The next requirement for the evaluation system is its adaptability, which determines that since the external environment, economic conditions, and the specifics of the logistics industry may change, the evaluation system must have the ability to adapt, taking into account new trends, market conditions, and potential threats.

The last requirement determines economic efficiency, that is, the evaluation system should be economically justified, and the costs of its operation should be optimal, so as not to create an additional financial burden on the company.

Compliance with these requirements will contribute to the creation of a reliable and effective financial security assessment system, which will allow the logistics company to maintain financial stability and promptly respond to changes in the market environment.

The next stage determines the formation of a system of indicators based on the main components of the model for assessing the financial security of a logistics company (see fig. 5). The main components of this indicator system are a group of financial indicators, a group of personnel indicators, a group of sustainable development indicators, and a group of indicators for assessing the impact of global challenges. These indicator groups have a direct impact on the financial security of a logistics company. All researchers determine the influence of various financial indicators on the financial security of the company, therefore the use of different groups of financial indicators is appropriate.

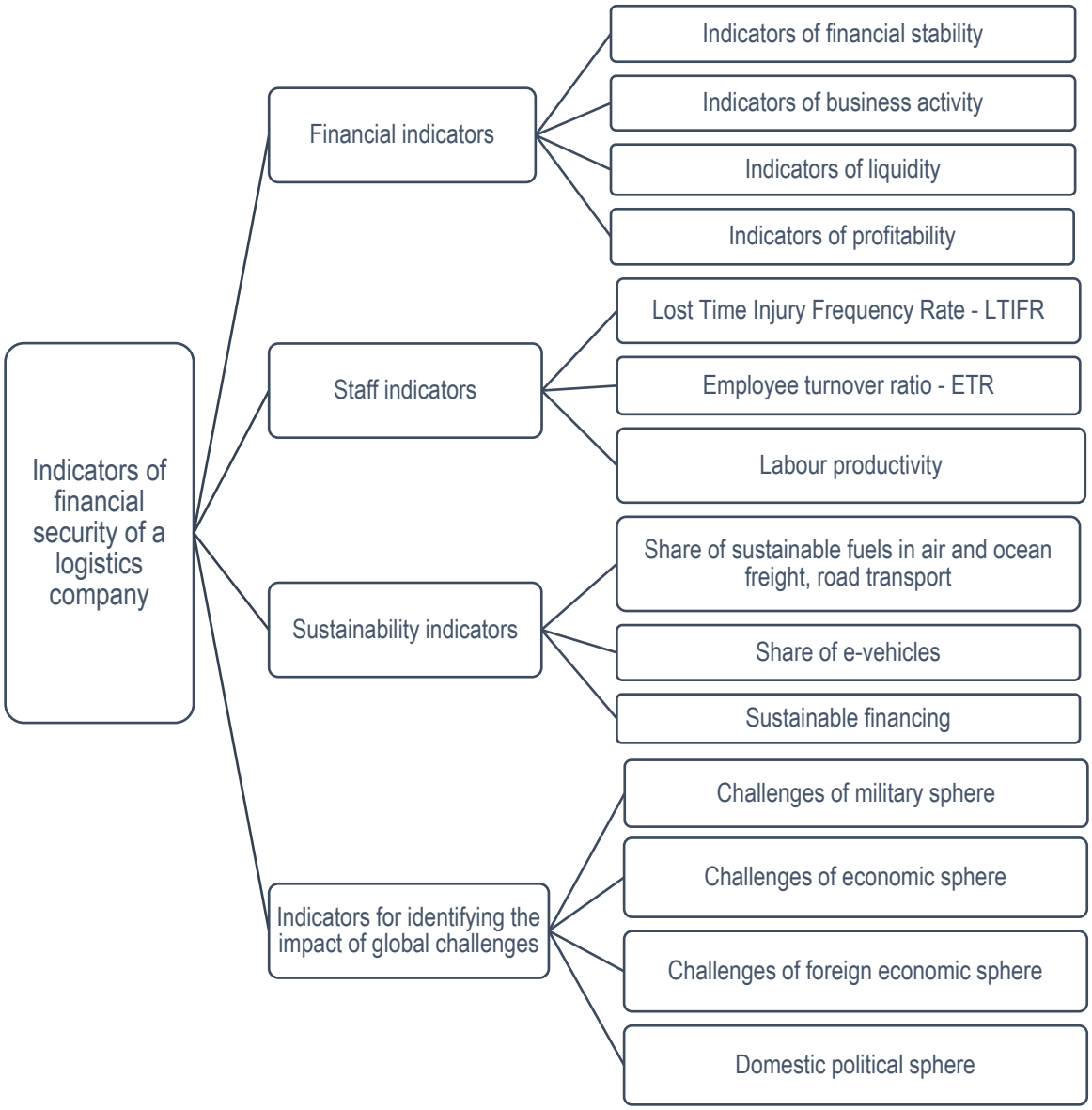

Figure 5. Indicators of financial security of a logistics company
Source: developed by the author

The main resource of a logistics company is its personnel, therefore the efficiency of a logistics company depends to a greater extent on the competencies of the personnel. Since personnel is the main resource, it is the carrier of not only competencies but also commercial secrets of the company, therefore the loss of personnel can threaten the financial security of the company.

Among indicators of sustainable development, the indicator of sustainable financing deserves special attention. Sustainable finance refers to the practice of directing financial flows, such as investments, loans, and lines of credit, to projects, companies, or initiatives that advance environmental, social, and governance (ESG) objectives. The goal is to support sustainable development while simultaneously achieving economic growth. Sustainable finance combines traditional financial criteria with an assessment of long-term environmental and social impacts, encouraging responsible investments that are aligned with sustainable development goals such as climate change mitigation, energy efficiency, biodiversity

protection, and equitable social development.

Each component of financial security is assessed based on defined groups of indicators, which are summarized based on an integral indicator of financial security.

Depending on the value of the integral indicator, strategies, and methods of countering threats to the financial security of the logistics company are determined. The last stage of the algorithm for assessing the level of financial security is correlated with the third stage of the financial security management mechanism - "Ensuring effective countermeasures against threats to the financial security of the logistics company." A logistics company can develop a package of preventive measures that can be used in the proactive management of financial security.

The fourth stage of the mechanism is "Implementation and control over the performance of planned measures to ensure a sufficient level of financial security of the logistics company", which consists of two components - implementation and control. Implementation involves the implementation of a set of measures that are implemented through the management of subsystems, which are defined in Fig. 2. Controls ensure that all processes meet financial security objectives by providing oversight and identifying any discrepancies for corrective action. Control is carried out by conducting a regular financial audit, which specifies periodic checks of financial records and processes to ensure compliance with internal policies and external regulations. In addition, an internal control mechanism that establishes a system of checks and balances to monitor compliance with financial plans, budgets, and policies may also be introduced.

The last stage of the mechanism - "Adaptation and correction of strategy" provides flexibility, allowing the logistics company to respond to new risks or economic changes, thereby ensuring long-term financial security. Corrective actions involve the development and implementation of corrective measures for individuals/each subsystem to ensure financial security, which is defined in Fig. 2 if any deviations are detected at the monitoring stage. Adaptation involves forming reactions to changes in the external environment, and modifying strategies (for example, changing investment tactics or risk management tactics) to better match new conditions.

The conceptual model of financial security management of a logistics company is summarized by evaluating the effectiveness of the logistics company's financial security management system, which allows to assess the overall state of financial security and evaluate the effectiveness of measures taken to ensure financial security and correct strategies in case of deviations from the plan.

Conclusions. So, the conceptual foundations of the logistics enterprise's financial security management system are determined by key principles, methods, and tools aimed at ensuring the stable functioning of the logistics company in the face of global challenges. The conceptual basis of the financial security management system of the logistics company should ensure its stability and ability to quickly adapt to external changes, and global challenges facing the logistics company. The financial security assessment system is the core of this model, thanks to which the logistics company will be able to conduct an integrated assessment of financial security, assess potential threats to its activities to ensure financial stability, and increase competitiveness in the face of global challenges..

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36-46
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MANAGEMENT OF FOOD SECURITY AND TRANSPORT SERVICES OF AGRICULTURAL ENTERPRISES OF THE GRAIN MARKET

Viktor Koval, Kateryna Kozak, Ihor Savenko, Valeriia Drozdova, Natalia Asaulenko, Iryna Honcharova. «Management of Food Security and Transport Services of Agricultural Enterprises of the Grain Market». *The article presents the results of a study of the state of transport support for agricultural producers as a basis for ensuring food security both within the country and in the international arena. The main types of transport involved in organizing transport services for various groups of agricultural products are described. The main directions for ensuring the high-quality and timely export of finished products from the places of their production are considered, especially grain crops and milling products, which play an important role in fulfilling the guarantees provided by Ukraine in the global food security mechanism. The methodology of statistical research is used as a tool for assessing the effectiveness of the analysis since the demand for transport services depends on the efficiency of agricultural enterprises, which, in turn, are very sensitive to natural and climatic influences. According to the results of the study, only 4% of the total number of road transports was carried out on orders from livestock producers, which means not only a low level of development of the transport service system for this group of agricultural producers, but may also be a consequence of imbalances in the development of this sector of agricultural production. The results obtained can be used to identify internal reserves for increasing the coverage of agricultural producers with transport services to meet domestic demand for food and reduce food imports due to the inability to provide domestic producers with reliable logistics services. Ensuring food security is a complex process that requires high-quality interaction between many industries and effective management by state authorities. Transport services for agricultural producers should become an effective tool for ensuring food security both in the domestic market of Ukraine and in fulfilling Ukraine's international obligations.*

Keywords*:* management, food security, grain market, transport services, transportation of grain and milled products, transportation of agricultural products of plant and animal origin

Віктор Коваль, Катерина Козак, Ігор Савенко, Валерія Дроздова, Наталя Асауленко, Ірина Гончарова «Управління продовольчою безпекою та транспортним обслуговуванням аграрних підприємств зернового ринку». *У статті наведено результати дослідження стану транспортного забезпечення сільськогосподарських товаровиробників як основи забезпечення продовольчої безпеки як усередині країни, так і на міжнародній арені. Охарактеризовано основні види транспорту, задіяні в організації транспортного обслуговування різних груп сільськогосподарської продукції. Розглянуто основні напрями забезпечення якісного та своєчасного вивезення готової продукції з місць її виробництва, особливо зернових культур та продуктів їх перемолу, які відіграють важливу роль у виконанні гарантій, які надає Україна в глобальному механізмі продовольчої безпеки. Як інструмент оцінки ефективності аналізу використовується методологія статистичних*

36-46
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досліджень, оскільки попит на транспортні послуги залежить від ефективності роботи сільськогосподарських підприємств, які, у свою чергу, є дуже чутливими до природно-кліматичних впливів. За підсумками дослідження, лише 4% від загальної кількості перевезень автомобільним трнаспортом було здійснено за замовленнями виробників тваринництва, що означає не тільки низький рівень розвику системи транспортного обслуговування цієї групи виробникев сільськогосподарської продукції, але й може бути наслідком диспропорцій у розвитку цієї галузі сільськогосподарського виробництва. Отримані результати можуть бути використані для виявлення внутрішніх резервів збільшення охоплення сільгоспвиробників транспортними послугами з метою забезпечення внутрішнього попиту на продовольство та зменшення імпорту продовольства через неможливість забезпечити вітчизняних товаровиробників надійними логістичними послугами. Забезпечення продовольчої безпеки - складний процес, що потребує якісної взаємодії багатьої галузей та ефективного керування з боку державних органів. Транспортне обслуговування виробників сільськогосподарської продукції має стати ефективним інструментом забезпечення продовольчої безпеки як на внутрішньому ринку України, так й при виконанні міжнародних зобовязань України.

Ключові слова: управління, продовольча безпека, зерновий ринок, транспортне обслуговування, перевезення зерна та продуктів перемолу, перевезення сільськогосподарської продукції рослинного та тваринного походження

Introduction. In the context of international specialization in agricultural production, the distribution of products across different countries is uneven. To ensure the direct consumption of agricultural goods, they must be transported over considerable distances. The management of transport services for agricultural enterprises addresses two key challenges: the efficient sale of agricultural products and the assurance of food security.

Transport services tailored for agricultural producers aim to guarantee seamless support for all stages of production, addressing the time-sensitive demands of the sector. The seasonal variability of agricultural operations necessitates a diverse fleet of transport vehicles and the implementation of an efficiently organized transportation management system (Burak et al., 2019). To foster optimal conditions for agricultural output, careful coordination of product flows is essential, especially in light of possible alterations to the quality or properties of goods during transit (Davydenko, Titenko, Koval, & Skrypnyk, 2024). This underscores the critical importance of bolstering security measures, which form an integral component of the transport management framework for agricultural enterprises.

The development of agricultural markets depends on the methods used to ensure a sufficient supply of goods (Penev, Shyriaieva, Legeza, Merkulov, & Honcharova, 2024). Uneven production capabilities across different regions, climate changes that continuously worsen conditions for growing traditional crops, and the passive approach of some producers in seeking new crops and adapting to evolving agricultural conditions all contribute to the growing importance of transport infrastructure for grain producers in ensuring food security (Koval et al., 2025).

However, established supply chains are not always optimal and may fail to align with shifting production conditions and crop patterns influenced by climate change. Effective management of transport logistics for agricultural producers is, therefore, a key factor in enhancing the efficiency of agricultural production (Honcharova et al., 2024).

In the grain market, an essential component of transport service management is the organization of grain and pre-milled product deliveries to ports. Since most shipments cover long distances, sea transport

plays a crucial role (Honcharova & Metil, Finding areas of innovative activity of the enterprise, 2022). This study aims to analyze how different delivery methods for grain and pre-milled products impact the final cost of goods, which form the foundation of food security.

Literature review. Globalization and local integration create conditions that enhance the ability of agricultural producers to supply their products, which is reflected in the level of profitability of agricultural production. Rau et al. (2023) argue that increasing the mobility of goods is easier in the presence of established transportation channels, but technological barriers may arise in creating new transport links, especially in the process of supporting cross-border trade (Rau, Antoniou, Busch, & Hariharn, 2023). Matyushenko and Redko (2020) point to the need to eliminate Ukraine's transport isolation in the field of rail transport due to differences in rail standards, which confirms the view of Rau et al. on the need to overcome technological discrepancies to ensure international mobility (Matyushenko & Redko, 2020).

The impact of globalization processes on world markets is highlighted by Sabri (2024), paying special attention to the food market as one of the most socially significant in the framework of global cooperation (Sabry, 2024). According to van den Akker et al. (2024), there are currently some problems that can be solved in the process of transporting food supply networks since existing established supply chains do not meet the global demand for food, especially in East African countries (van den Akker, Fabbri, & Slater, 2024). Thow and Nisbett (2019) consider the issues of the stability of food systems depending on the quality of transport service management for agricultural producers, paying attention to the issues of timely adjustment of transport flows to implement qualitative changes in the system of ensuring the stability of food supplies (Thow & Nisbett, 2019, 394(10200)).

Particular attention is paid by various authors to environmental issues, the management of which is a component of transport service management. Gie et al. (2024) consider global trends in changes, including in the field of transport, necessary for the sustainable development of the environment (Gie, McNeill, & Bannerman, 2024). Mia et al. (2022) emphasize the impact of green entrepreneurship on social changes in the world and draw attention to the possibilities of green entrepreneurship in the provision of transport services to agricultural producers, including grain producers (Mia, et al., 2022).

As a solution to the food security problem, Tsai et al. (2020) propose to develop smart and sustainable supply chains in cooperation with logistics, for which it is proposed to digitally reorganize existing supply chains, but this reorganization is largely aimed at tracking the location of food cargo, changing vehicles, but does not consider the issues of providing backup methods of food delivery, which does not contribute to strengthening food security (Tsai, Kosacka-Olejnik, & Golinska-Pawson, 2020). Skyba et al. (2023) consider the possibilities of clusters in the economic development strategy, but do not take into account the need to implement modules for ensuring food security in city clusters (Skyba et al., 2023). Despite the diverse study of the possibilities of improving transport services for agricultural producers, and especially grain crops, which form the basis of food security in various territories, and for which Ukraine is one of the main suppliers of food, transport issues require further study in order to improve the management of both transport services and food security.

Description of the research object. One of the priority areas of economic development in Ukraine is the development of agricultural production since there are production resources available and there is significant potential for increasing the efficiency of agricultural production. Over the past 35 years, there has been a varying

percentage of value added to Ukraine's gross domestic product generated in the fields of agriculture, forestry, and fisheries (Figure 1).

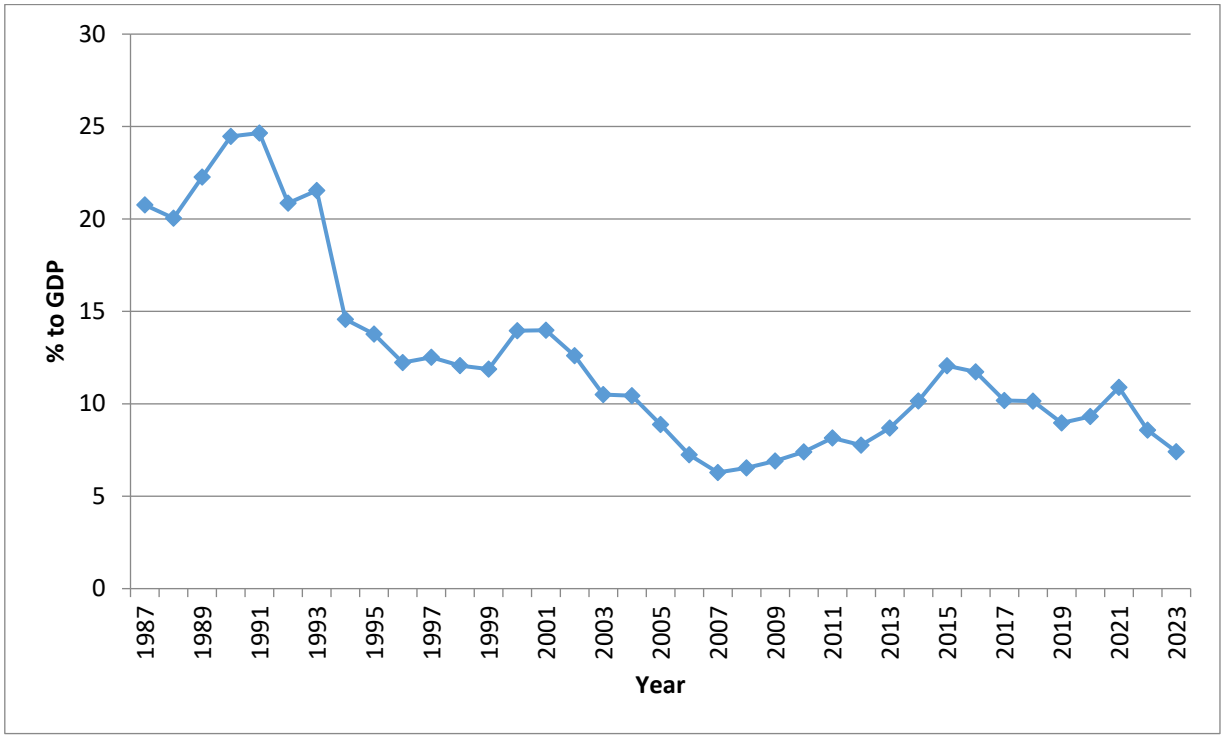

Figure 1. Percentage of value added in Ukraine's GDP generated in agriculture, forestry, and fishing.

Source: Compiled based on (World Bank, 2024).

Significant fluctuations in the percentage of added value (maximum 24.65% in 1993, minimum 6.28% in 2007) are explained by different levels of added value creation in the field of industrial production. However, for Ukraine, the percentage of added value from gross domestic product significantly exceeds the world average, which indicates significant volumes of agricultural production and the constant demand for transport services for agricultural producers.

Since different territories are differently provided with transport infrastructure, there are imbalances in the transport services for agricultural producers.

The role of road transport in providing agricultural producers. In Ukraine, the most developed system of automobile support in the field of transport services is the system of automobile support. Therefore, the vast majority of agricultural products are transported by road. According to the results of the observation conducted by the State Statistics Service of Ukraine for the period from 2017 to 2021, the vast majority of agricultural products transported by road are grain products (78-80%), and among other types of plant products, potatoes (0.4%), sugar beets (3%), other fresh vegetables and fruits (3.4%), live plants and flowers (0.1%) and other plant products (10.1%).

Among animal products, live animals account for 0.2% of the total volume of cargo transported by road for the period from 2017 to 2021, milk accounts for 2.1%, and other raw materials of animal origin account for 0.4% (Figure 2).

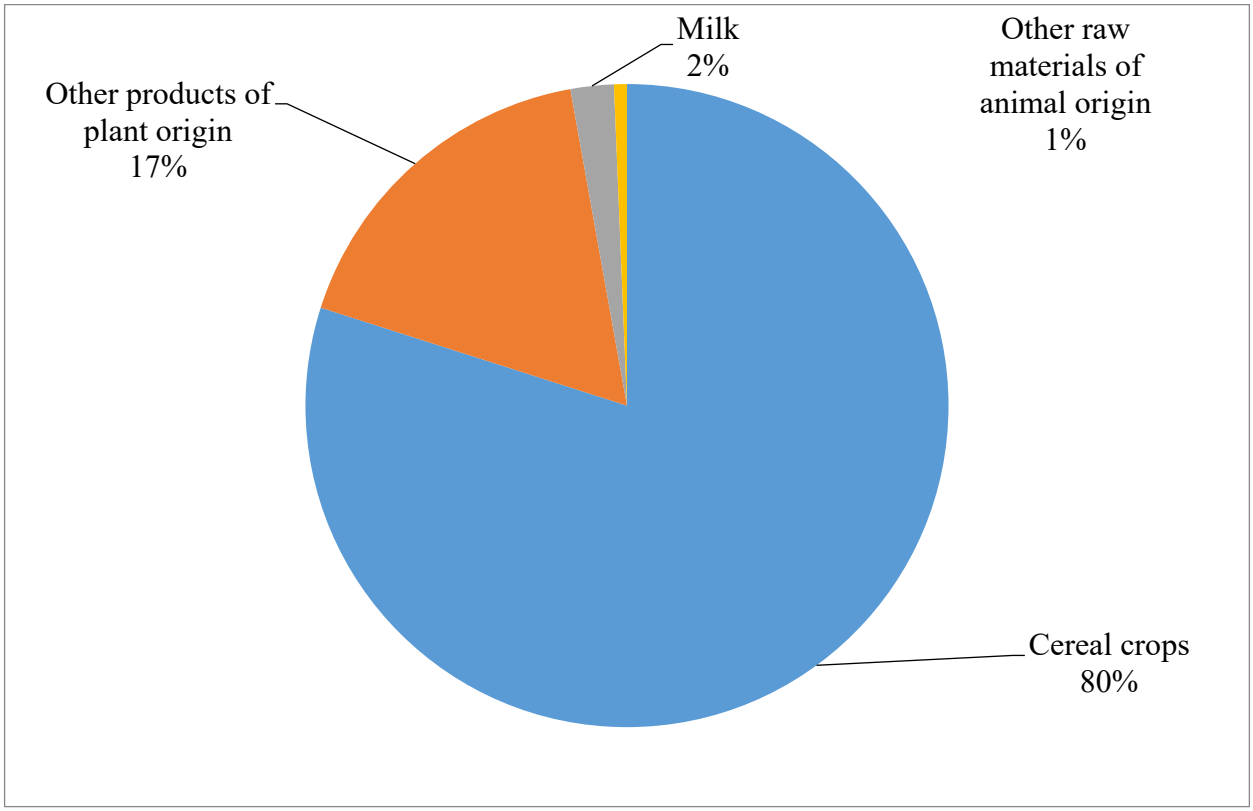

Figure 2. Transportation of agricultural products by road.
Source: Compiled based on State Statistics Service of Ukraine (2024).

To provide road transport services for the transportation of plant products, it is necessary to take into account the specifics of the goods, the transportation of which was ordered by agricultural producers. For the transportation of vegetables and fruits, which are transferred by the customer of transport services in specialized containers, it is necessary to provide for the reverse circulation of the container, the transportation of which should be carried out in the most compact form to save transport resources. Also, when transporting fruits and vegetables, depending on the density of the fruits, commodity volumes should be provided, taking into account natural waste due to possible errors in sorting products.

When transporting small-scale crop products, such as dill, green onions, it is necessary to take into account temperature regimes and air humidity levels (Shmygol, Luczka, Harbar, Koval, & Cioca, 2024, No 1, Vol.72). When transporting flowers, seedlings and seedlings, there are also features that must be taken into account when planning transport services for agricultural producers.

Road transport is actively used in the transportation of agricultural products in international traffic. Figure 3 presents general information on the transportation of agricultural products by road in international traffic for the period from 2017 to 2021.

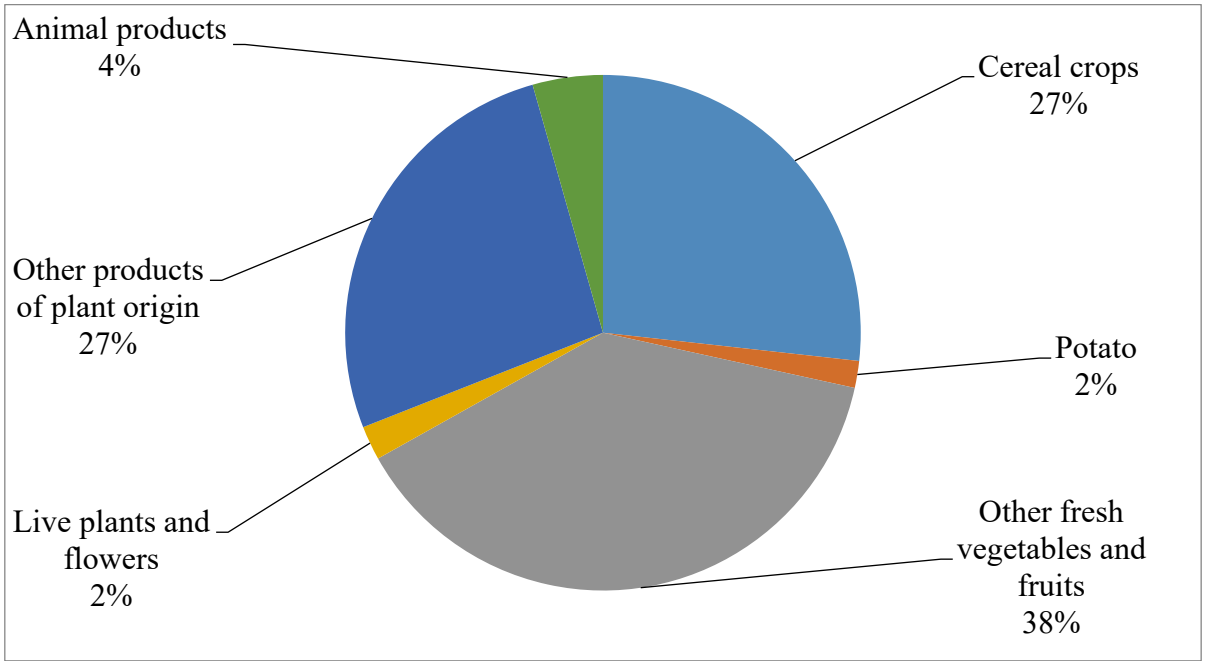

Figure 3. Transportation of agricultural products by road in international traffic.
Source: Compiled based on State Statistics Service of Ukraine (2024).

In international traffic, the vast majority of products transported within the framework of transport services for agricultural producers are fresh vegetables and fruits (38%). This is due to the high mobility of road transport, the convenience of loading and unloading operations, and the high density of roads in areas where these types of agricultural products are actively produced. Under these conditions, it is observed that other plant products account for 27% of the total volume of transportation within the framework of transport services for agricultural producers by road in international traffic. In general, crop products account for 96% of the total volume of transportation by road in international traffic, which is explained by the significant mobility of crop producers, unlike livestock producers (State Statistics Service of Ukraine. Agriculture, forestry and fisheries).

In contrast to the total volume of road transport, grain has a much smaller share in international transport (27% versus 80%), which is due to the use of other types of transport for grain producers to provide transport services in the implementation of international agreements. A significant part of the transportation of grain and milling products is carried out by rail and water transport. In general, rail and water transport for the period from 2016 to 2020 transported mainly grain and milling products from the variety of agricultural products (Figure 4).

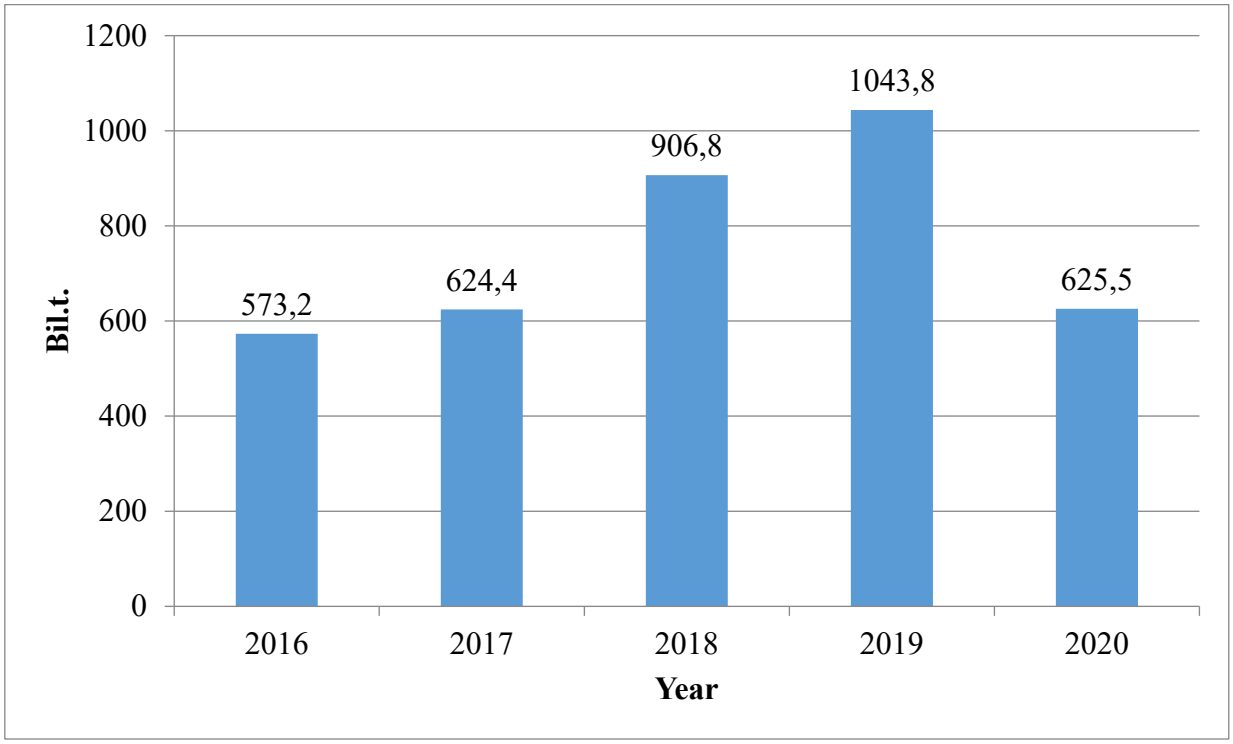

Figure 4. Transportation of grain and milling products by rail and water transport.
Source: Compiled based on State Statistics Service of Ukraine (2024).

The role of railway transport in ensuring the export of agricultural products. Railway transport provides transport services to grain producers only within the territory of Ukraine, which is explained by the difference in tracks between Ukraine and the EU countries and other European countries. The exception is the railway tracks in Moldova, which have the same standard as the tracks in Ukraine. However, due to the lack of demand for grain from Moldova, these tracks are used only for transit transportation of grain to the seaport of Reni, which provides transport services for the functions of a river and seaport at the same time. The port, which is located in the South-Western part of Ukraine, at the junction of the Ukrainian, Romanian and Moldovan borders, and the intersection of four transport corridors (Cretan No. 7 and No. 9, Eurasian and Black Sea), has great potential, especially in the field of international trade, however, deliveries to this port can only be carried out either by road or by rail in transit through the territory of Moldova.

The role of water transport in ensuring the export of agricultural products. Since there are certain specifics in the transport service of grain and milled products producers, such as large batches of products, the threat of fires during transportation, complex loading and unloading processes that require stationary specialized equipment, transport service by water transport is in the greatest demand among grain and milled products producers operating in the international food security system. Figure 5 presents the total volumes of grain and milled products transported by water from 2016 to 2020.

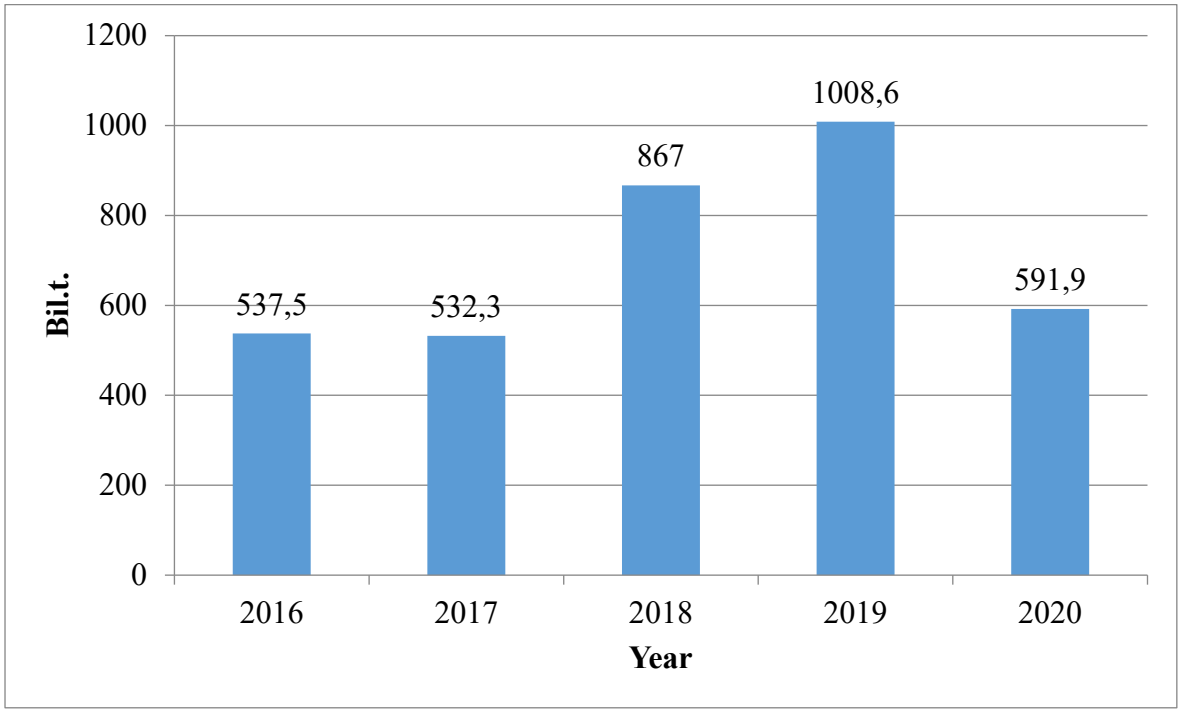

Figure 5. Transportation of grain and milling products by water in 2016-2020.
Source: Compiled based on State Statistics Service of Ukraine (2024).

The production of grain and milled products significantly exceeds Ukraine's domestic needs for these types of agricultural products, therefore, a significant part of the transportation is provided by transport service providers that carry out transportation by water modes to grain and milled products producers when carrying out international transportation (Figure 6).

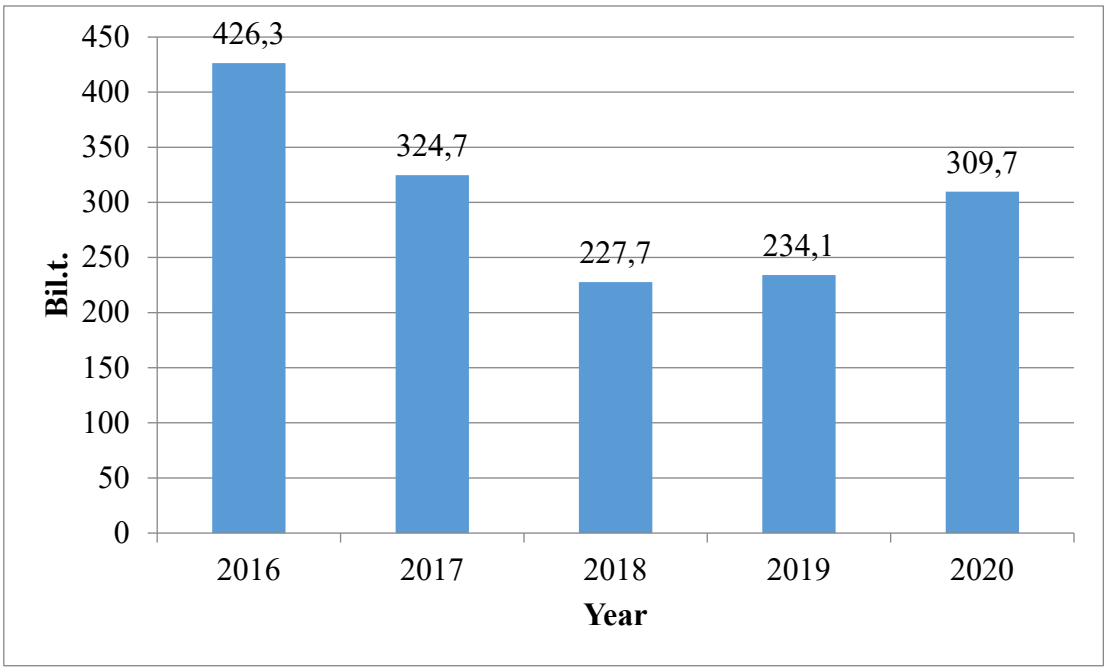

Figure 6. Transportation of grain and milling products by water transport in international traffic.
Source: Compiled based on State Statistics Service of Ukraine (2024).

Ukraine's priority in the production of grain and milled products, formed in the process of international specialization, plays an important role in creating a system of international food security and shapes the volumes of gross domestic product and exports, which affects Ukraine's position at the international level.

Conclusions. The study of the transport support system of agricultural producers showed that the main commodity flow both in the domestic and foreign markets is grain milled products. When transported by road, grain and milled products make up 80% of the total volume of transportation, which indicates the stability of demand for services for the transportation of this type of agricultural product, especially within the domestic market, since in foreign trade operations, grain transportation makes up only 27% of the total volume of goods transported. Consequently, road transport plays a more significant role in ensuring food security within the country.

Rail transport is also actively involved in the transportation of grain and milled products, however, it should be considered to a greater extent as an intermediate link in the implementation of international contracts for the supply of grain and milled products as part of ensuring global food security. On average, 750 million tons of grain and milled products are transported per year, which is about 30% of annual world consumption. However, due to technical limitations, it is not possible to use rail transport for mass grain exports.

Water transport is actively used to provide transport support for international grain supply contracts, transporting on average more than 300 million tons of grain and milled products per year, which is 14% of global grain consumption. However, to expand the possibilities of providing grain producers with water transport services, infrastructure solutions are needed that will facilitate access to port infrastructure facilities for transport companies engaged in intermediate grain transportation.

In general, taking into account the volumes of grain and milled products, the transportation of which is carried out within the framework of transport services for agricultural producers, the implementation of agreements on ensuring food security both within Ukraine and within the framework of international cooperation is carried out. This study did not contain an examination of the quality and level of development of digital components of the grain producers' transport system, which may serve as subjects for further research.

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TRANSPARENCY AND SUSTAINABILITY: A NEW PARADIGM FOR SUPPLY CHAIN MANAGEMENT

Larysa Shchekhovska. "Transparency and sustainability: a new paradigm for supply chain management". *This research examines the evolving paradigm of supply chain management that integrates transparency and sustainability as core operational principles. The study investigates how modern supply chains are transitioning from traditional models focused primarily on efficiency and cost reduction to more holistic frameworks that incorporate environmental stewardship, social responsibility, and economic sustainability. Through comprehensive analysis, the research identifies transparency as a critical enabler of sustainable supply chain practices, introducing a six-dimensional framework that encompasses traceability, transaction, impact, policy and commitment, activity, and effectiveness information. The study presents a systematic four-step process for building transparency in supply chains: identifying and prioritizing risks, visualizing risks through mapping techniques, implementing transparency levers to bridge information gaps, and developing robust management and monitoring systems. The findings demonstrate that supply chain transparency not only mitigates risks related to environmental and social impacts but also creates long-term value for all stakeholders. The paper argues that transitioning from traditional monitoring approaches to transparency-centered sustainability management systems encourages supplier ownership of sustainability initiatives and fosters collaborative relationships throughout the supply chain. This paradigm shift ultimately transforms supply chain management from a potential source of reputational and operational risk to a strategic driver of competitive advantage and sustainable development. The practical implications include methodologies for companies to implement transparent and sustainable supply chain practices that align with global standards such as the United Nations Global Compact principles while improving operational resilience and stakeholder trust.*

Keywords*:* supply chain sustainability, transparency, corporate responsibility, environmental governance, traceability, risk management, sustainable development, supplier engagement, monitoring systems, transparency levers, supplier ownership

Лариса Щеховська. "Прозорість і сталість: нова парадигма управління ланцюгом поставок". *Це дослідження розглядає еволюціонуючу парадигму управління ланцюгом поставок, яка інтегрує прозорість і сталість як основні операційні принципи. Дослідження вивчає, як сучасні ланцюги поставок переходять від традиційних моделей, орієнтованих переважно на ефективність та зниження витрат, до більш цілісних концепцій, що включають екологічне управління, соціальну відповідальність та економічну сталість. Шляхом комплексного аналізу дослідження визначає*

47-53
v.30 (2025)
https://smart-scm.org

прозорість як критичний фактор, що сприяє сталим практикам у ланцюгах поставок, та представляє шестивимірну модель, яка включає інформацію про простежуваність, транзакції, вплив, політику та зобов'язання, діяльність та ефективність. Дослідження представляє систематичний чотириетапний процес побудови прозорості в ланцюгах поставок: ідентифікація та визначення пріоритетності ризиків, візуалізація ризиків за допомогою методів картографування, впровадження важелів прозорості для подолання інформаційних прогалин, а також розробка надійних систем управління та моніторингу. Результати демонструють, що прозорість ланцюга постачання не лише зменшує ризики, пов'язані з екологічними та соціальними впливами, але й створює довгострокову цінність для всіх зацікавлених сторін. У статті стверджується, що перехід від традиційних підходів моніторингу до систем управління сталим розвитком, орієнтованих на прозорість, заохочує постачальників брати на себе відповідальність за ініціативи зі сталого розвитку та сприяє розвитку співпраці у всьому ланцюгу поставок. Ця зміна парадигми зрештою перетворює управління ланцюгом постачання з потенційного джерела репутаційного та операційного ризику на стратегічний драйвер конкурентної переваги і сталого розвитку. Практичні наслідки включають методології для компаній щодо впровадження прозорих і сталих практик у ланцюгах постачання, які відповідають глобальним стандартам, таким як принципи Глобального договору ООН, водночас підвищуючи операційну стійкість та довіру зацікавлених сторін.

Ключові слова: сталий розвиток ланцюгів постачання, прозорість, корпоративна відповідальність, екологічне управління, відстежуваність, управління ризиками, сталий розвиток, взаємодія з постачальниками, системи моніторингу, важелі прозорості, власність постачальників.

Introduction. In today's interconnected global economy, supply chain sustainability has emerged as a critical component of corporate responsibility and strategic management. As organizations navigate increasingly complex networks of suppliers, manufacturers, distributors, and customers, the need to address environmental, social, and economic impacts throughout the product lifecycle has become paramount. The traditional view of supply chains as mere operational mechanisms for delivering products and services has evolved into a broader understanding that recognizes their role in advancing sustainable development objectives.

Supply chain management now extends beyond the mere oversight of logistics and operations to encompass responsibility for environmental stewardship, social welfare, and ethical governance throughout the entire value network. This paradigm shift has been driven by multiple factors, including heightened consumer awareness, regulatory pressures, investor demands, and the recognition that sustainable supply chains can deliver both competitive advantage and positive societal impact.

The concept of transparency has emerged as a fundamental principle in this new paradigm. Transparency in supply chains refers to the visibility of information across various dimensions, from traceability of products and materials to the disclosure of environmental and social impacts. It serves as both a tool for accountability and a mechanism for driving continuous improvement in sustainability performance.

Despite growing recognition of its importance, many organizations struggle to implement effective transparency and sustainability practices within their supply chains. This challenge stems from the complexity of global supply networks, information asymmetries, and the difficulty of coordinating sustainability efforts across multiple tiers of suppliers and partners.

This article examines the evolving paradigm of supply chain management that integrates transparency and sustainability as core operational principles. It explores theoretical frameworks for understanding

supply chain transparency, presents practical approaches for building transparent and sustainable supply chains, and discusses the transition from traditional monitoring to more collaborative models of sustainability management.

Analysis of recent researches and publications. The academic literature on supply chain sustainability and transparency has expanded significantly in recent years, reflecting growing interest from both researchers and practitioners. Early work in this field primarily focused on environmental aspects of supply chain management, such as green supply chain management and environmental performance measurement. However, more recent research has adopted a more comprehensive approach that integrates environmental, social, and economic dimensions of sustainability.

Scholars have developed various frameworks for conceptualizing and implementing sustainable supply chain management. Gardner et al. provide a foundational framework for understanding transparency in global commodity supply chains, highlighting the multidimensional nature of transparency and its role in improving sustainability outcomes. Building on this conceptual foundation, Buck explores the practical dimensions of transparency in supply chains, examining how organizations can implement transparency initiatives that create meaningful change. The relationship between transparency and corporate investments in sustainability is examined by Rueda et al., who analyze the selection of instruments in the agri-food industry. More recent publications from Tredence Inc. and The International Center for Trade Transparency Limited focus on the essential nature of transparency and traceability for sustainable supply chains, highlighting emerging technologies and approaches that enable greater visibility.

Despite these advances, gaps remain in our understanding of how organizations can effectively transition from traditional supply chain management approaches to more transparent and sustainable models. Additionally, more research is needed on the specific mechanisms through which transparency drives improvements in sustainability performance and how organizations can overcome barriers to implementation.

The purpose and objectives of the study. The primary purpose of this research is to examine the integration of transparency and sustainability principles into supply chain management practices, exploring how this new paradigm transforms traditional approaches and creates value for organizations and their stakeholders.

Specific objectives of the study include: to define and conceptualize supply chain sustainability and transparency within the context of contemporary business practices and global sustainable development objectives; to develop a comprehensive framework for understanding different dimensions of supply chain transparency and how they contribute to improved sustainability performance; to identify practical approaches for building transparent and sustainable supply chains, including risk assessment, visualization, information gathering, and management processes; to analyze the mechanisms through which transparency and sustainability practices create business value while advancing broader societal goals.

By addressing these objectives, the study aims to contribute to both theoretical understanding and practical implementation of transparent and sustainable supply chain management practices.

Basic material and results. Supply chain sustainability can be defined as "the management of environmental, social and economic impacts, and the encouragement of good governance practices, throughout the lifecycles of goods and services." The objective of this approach is to create, protect, and grow long-term value for all stakeholders involved in bringing products and services to market [1].

A sustainable supply chain considers the environmental and social impact of a product's journey through the entire supply chain, from raw materials to final delivery. However, it is important to recognize that sustainability is a dynamic concept that evolves over time. As our understanding of environmental and social challenges deepens, the criteria for what constitutes a "sustainable" supply chain will inevitably change.

Transparency, within this context, refers to the ability of businesses not only to "know internally" that they are exercising due diligence but also to "show externally" that this is the case. This concept has both normative and substantive dimensions. Normatively, transparency is viewed as a tool to serve principles of democracy, participation, and accountability. Substantively, it encompasses concrete criteria necessary to improve sustainability practices, including monitoring, disclosure, reporting, and verification [3].

To provide a more comprehensive understanding of supply chain transparency, we propose a framework consisting of six interrelated dimensions of information:

1) Traceability information that reports on the different actors involved in a supply chain, their roles, and the connections between actors and production localities.

2) Transaction information that reports on purchasing practices and investment decisions of different supply chain actors, helping identify the main beneficiaries and those who share responsibility for sustainability concerns [4].

3) Impact information that reports on social and environmental impacts associated with specific stages in a supply chain, setting a baseline for assessing performance.

4) Policy and commitment information that refers to actors' policies and commitments to increase sustainability, providing transparency on differences in the levels and strengths of policies adopted by different actors [10].

5) Activity information that reports on actions taken by supply chain actors to deliver on their targets and commitments, showing how behavior is changing.

6) Effectiveness information that reports on the effectiveness of interventions in reducing negative impacts and improving performance, showing how much progress is being made.

These dimensions form a cyclical process of assessment and intervention necessary for improving sustainability conditions on the ground.

A Four-Step Process for Building Transparency. For organizations seeking to implement more transparent supply chains, it's recommend a four-step process:

Step 1. Identifying and Prioritizing Risks. Given the numerous risks inherent in most supply chains, organizations need a systematic approach to determine which to focus on. Supply chain risks can be grouped into four broad categories: macroeconomic, extended value chain, operational, and functional. Using tools such as the Failure Modes and Effects Analysis, organizations can review potential risks from each category and prioritize them based on severity, likelihood of occurrence, frequency, and ease of detection.

Step 2. Visualizing Risks. Once risks are identified and prioritized, organizations can map the volume of products flowing around the world using tools like Google Earth or 3D mapping. This visual representation reveals points of vulnerability where large volumes of products flow from particular suppliers into high-risk regions. The transparency mapping process involves identifying suppliers and business partners, isolating where visibility is most limited ("information gaps"), and determining who might help close those gaps.

Step 3. Using transparency levers to close information gaps. After highlighting information gaps, organizations can employ various transparency levers to bridge them [5]. These may include:

47-53
v.30 (2025)
https://smart-scm.org

– anonymous SMS text surveys for supplier feedback;

– third-party verification and certification;

– supply chain mapping and traceability systems;

– stakeholder engagement and collaboration;

– technology solutions such as blockchain or IoT;

Step 4. Managing and monitoring. A sustainable transparency program must go beyond closing information gaps to help organizations learn from and manage the insights gained. This can be achieved through supplier databases containing compliance and risk data, with algorithms to sort suppliers into risk tiers. More sophisticated systems might integrate real-time risk indicators, visualization tools, and predictive analytics capabilities.

The ultimate goal of supplier engagement should be supplier ownership of sustainability, which occurs when suppliers integrate responsible practices into their mission, strategy, and decision-making. While monitoring and remediation are essential for understanding risks, they have limitations in addressing root causes or establishing forward-looking expectations [9].

Both companies and suppliers have roles in enabling supplier ownership: Companies should:

– share relevant business information with suppliers;

– build long-term relationships;

– create incentives for sustainability;

– expect improvements to sustainability management systems;

– encourage and reward transparency;

– be sensitive to how their business practices impact suppliers' ability to meet sustainability expectations.

Suppliers should:

– demonstrate personal executive commitment;

– incorporate sustainability into strategic planning;

– demonstrate continuous improvement;

– proactively communicate challenges and progress;

Leading companies are building supplier ownership through the development of sustainability management systems, incorporating evaluation of these systems into audit protocols, providing training and consulting for suppliers, and instituting improvement ladders that emphasize continuous improvement [8].

The use of different types of information, as mediated by different transparency processes and access limitations, can help inform and shape decisions relating to the four core challenges of supply chain sustainability governance (Fig. 1): how to untangle the complexity of global supply chains and identify starting points for efforts to improve their sustainability, how to manage the different risks associated with unsustainable production and trade practices, how to improve conditions on the ground, and how to assess progress against different targets and baselines, and understand the extent to which a given set of interventions places the trade of a given commodity on a more sustainable or even transformational path.

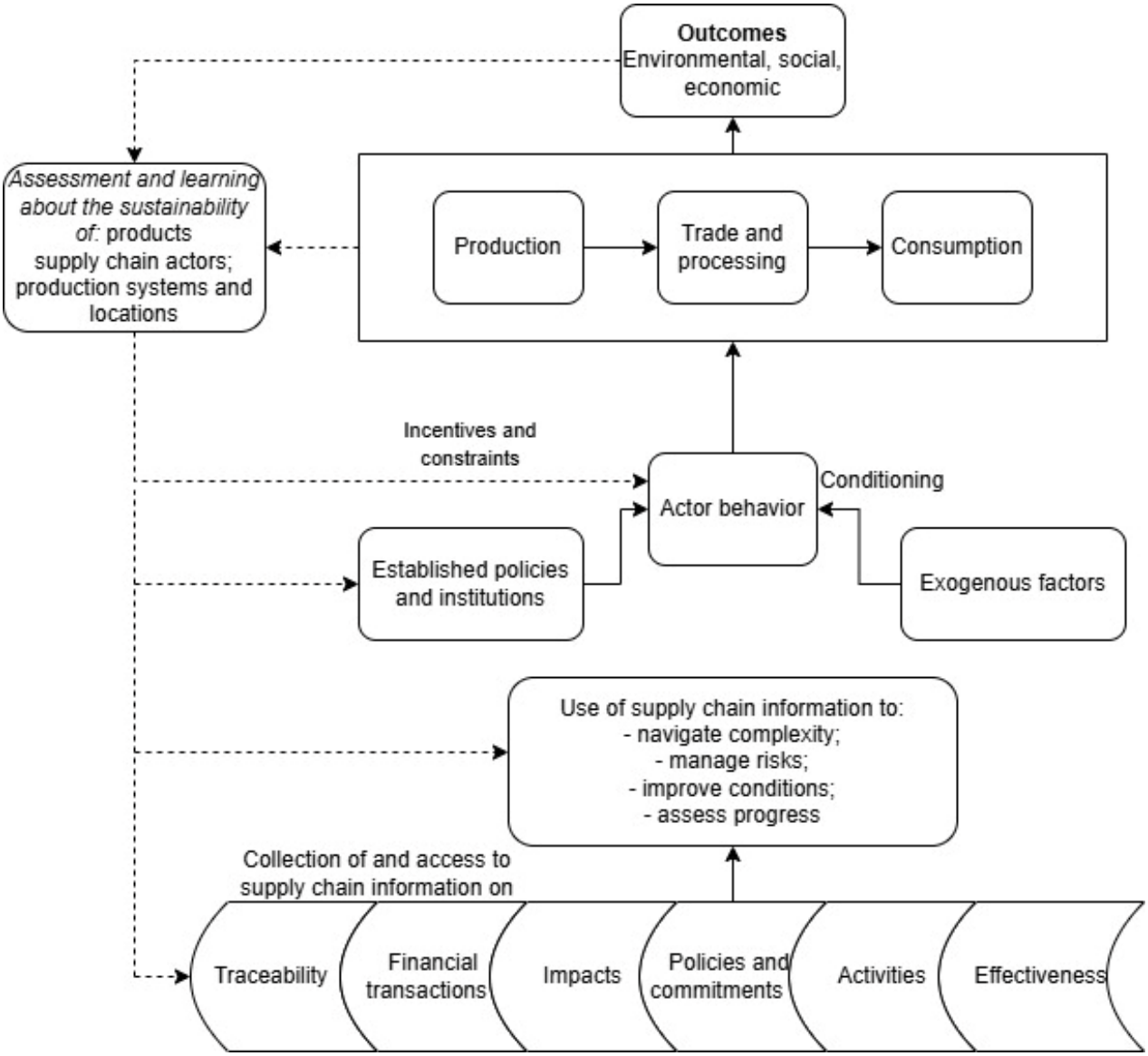

Figure 1. The relationships between supply chain information, transparency, and supply chain sustainability governance

Source: developed by the author

Conclusions. This research has examined the emerging paradigm of supply chain management that places transparency and sustainability at its core. Several key conclusions can be drawn:

First, supply chain sustainability represents a fundamental shift in how organizations conceptualize their responsibilities, extending them beyond direct operations to encompass the entire lifecycle of products and services. This approach recognizes that in today's globalized economy, outsourcing business operations does not mean outsourcing responsibilities or risks.

Second, transparency serves as both an enabler and a driver of sustainable supply chain practices. The six-dimensional framework presented in this study – encompassing traceability, transaction, impact, policy, activity, and effectiveness information – provides a comprehensive approach for understanding and implementing transparency in supply chains.

Third, building transparent and sustainable supply chains requires a systematic approach. The four-step process outlined in this research – identifying and prioritizing risks, visualizing risks, using transparency levers, and managing and

monitoring – offers a practical roadmap for organizations seeking to enhance transparency in their supply chains.

Fourth, the transition from traditional monitoring approaches to more collaborative models that emphasize supplier ownership represents a critical evolution in supply chain sustainability. This shift recognizes that lasting improvements in sustainability performance require suppliers to internalize sustainability values and integrate them into their business strategies and operations.

Finally, supply chain transparency and sustainability create value not only by mitigating risks but also by driving innovation, enhancing brand reputation, strengthening stakeholder relationships, and contributing to broader sustainable development objectives.

As organizations continue to navigate complex global supply networks, the principles of transparency and sustainability will become increasingly central to effective supply chain management. By embracing this new paradigm, organizations can transform their supply chains from potential sources of risk to strategic assets that create value for the business and society.

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IMPLEMENTATION OF INNOVATIVE METHODS FOR MANAGING HUMAN RESOURCE DEVELOPMENT IN AGRIBUSINESS ENTERPRISES

Olga Fedyk. «Implementation of innovative methods for managing human resource development in agribusiness enterprises». *This article is dedicated to the theoretical justification and practical aspects of implementing innovative methods for managing human resource development in agribusiness enterprises. The relevance of the research topic is explained by the urgent need to modernize the traditional human resource management system amid dynamic economic transformations, increasing competition, labor market instability, and rapid technological progress. The study emphasizes that traditional approaches to human capital development no longer meet the new requirements of the agribusiness sector. Special attention is paid to the need for introducing innovative tools and methods to improve employee training efficiency, enhance their ability to adapt to technological innovations, and contribute to the overall competitiveness of enterprises.*

The article outlines the main innovative methods that can be applied to human resource development, including e-learning technologies, gamification, adaptive learning, as well as coaching, buddying, shadowing, and secondment methods. The study highlights the flexibility and accessibility of e-learning for workers in the agricultural sector, which allows them to acquire knowledge without interrupting core production processes, a critical factor in the seasonal nature of agricultural activities. Furthermore, the use of gamification elements as a motivational tool is discussed, as it enhances employee engagement and promotes the development of both professional and soft skills. Special attention is given to adapting the content of training to regional features of agricultural production, such as climate conditions, soil types, and the specifics of crop cultivation. Coaching is considered as a means of individual support aimed at unlocking employees' potential, developing leadership skills, and addressing specific challenges in agricultural production. The buddying and shadowing methods are analyzed as effective tools for knowledge and experience transfer within the workforce, fostering the smooth integration of new employees and the spread of best practices. The article argues for the integration of the concept of continuous learning into the corporate culture of agribusiness enterprises. Additionally, the importance of involving employees in the development and improvement of training programs is highlighted, as this will enhance their motivation and foster a sense of responsibility for both personal and organizational development.

In conclusion, the article asserts that the implementation of innovative methods for managing human resource development is a key factor in ensuring the sustainable development and competitiveness of agribusiness enterprises. The introduction of innovative approaches to human resource development will not

only contribute to the improvement of qualifications and the acquisition of professional skills but also stimulate employees' creativity, initiative, and readiness for change, which will, in turn, contribute to the successful development of agricultural production in the context of the digital economy and technological progress.

***Keywords**:* personnel management, agro-industrial complex, innovative methods, e-learning, gamification, coaching, skills development, lifelong learning

Ольга Федик. «Впровадження інноваційних методів управління розвитком персоналу на підприємствах агропромислового комплексу». *Стаття присвячена теоретичному обґрунтуванню та практичним аспектам впровадження інноваційних методів управління розвитком персоналу на підприємствах агропромислового комплексу. Актуальність теми дослідження пояснюється нагальною необхідністю модернізації традиційної системи управління людськими ресурсами в умовах динамічних економічних трансформацій, зростаючої конкуренції, нестабільності ринку праці та стрімкого технологічного прогресу. У дослідженні підкреслюється, що традиційні підходи до розвитку людського капіталу більше не відповідають новим вимогам агропромислового сектору. Особлива увага приділяється необхідності впровадження інноваційних інструментів та методів для підвищення ефективності підготовки персоналу, його здатності до адаптації до технологічних новацій і внеску в загальну конкурентоспроможність підприємств.*

У статті окреслено основні інноваційні методи, що можуть бути застосовані для розвитку персоналу, зокрема технології електронного навчання (e-learning), гейміфікацію, адаптивне навчання, а також методи коучингу, buddying, shadowing і secondment. У дослідженні акцентовано увагу на гнучкості та доступності електронного навчання для працівників аграрної сфери, що дає змогу здобувати знання без відриву від основних виробничих процесів, що є особливо важливим у контексті сезонного характеру сільськогосподарської діяльності. Крім того, обговорено використання елементів гейміфікації як інструменту мотивації, що підвищує залученість працівників і сприяє формуванню як професійних, так і м'яких навичок. Особлива увага приділена адаптації змісту навчання до регіональних особливостей аграрного виробництва, зокрема кліматичних умов, типів ґрунтів та специфіки вирощування культур. Коучинг розглядається як засіб індивідуальної підтримки, спрямований на розкриття потенціалу працівників, розвиток лідерських навичок і вирішення специфічних завдань у сільськогосподарському виробництві. Методи buddying і shadowing аналізуються як ефективні інструменти передачі знань та досвіду в межах трудового колективу, що сприяє плавній інтеграції нових працівників і поширенню найкращих практик. У статті аргументується необхідність інтеграції концепції безперервного навчання в корпоративну культуру підприємств агропромислового комплексу. Додатково підкреслюється важливість залучення працівників до розробки та вдосконалення навчальних програм, що сприятиме зростанню їхньої мотивації та формуванню почуття відповідальності за особистий і організаційний розвиток.

У підсумку зазначається, що впровадження інноваційних методів управління розвитком персоналу є ключовим фактором забезпечення сталого розвитку і конкурентоспроможності підприємств агропромислового комплексу, адже впровадження інноваційних підходів до розвитку персоналу не лише сприятиме підвищенню кваліфікації та набуттю професійних навичок працівників, а й стимулюватимуть їхню креативність, ініціативність та готовність до змін, що в цілому сприятиме успішному розвитку аграрного виробництва в умовах цифрової економіки та технологічного прогресу.

Ключові слова: управління персоналом, агропромисловий комплекс, інноваційні методи, електронне навчання, гейміфікація, коучинг, розвиток компетенцій, безперервне навчання.

The relevance of the problem. In the current context of economic transformation and the active implementation of digital technologies, the issue of effective personnel development management in agro-industrial enterprises is becoming increasingly important. Given the growing competition, labor market instability, and the continuous renewal of technological processes, there is an objective need to apply innovative methods of human resource management. The relevance of this issue is driven by the fact that traditional approaches no longer provide sufficient flexibility and efficiency to meet the new challenges facing the agricultural sector.

The implementation of innovative methods for managing personnel development is crucial not only for increasing labor productivity but also for ensuring the competitiveness of enterprises in both domestic and international markets. The connection with significant scientific and practical objectives is reflected in the necessity to seek new models of professional training, to develop employees' leadership potential, to introduce systems for continuous competence development, and to adapt personnel to the use of modern agricultural technologies. The achievement of these objectives requires a comprehensive approach that integrates the latest theoretical advancements with successful practical experience in managing human capital within the agro-industrial production sector.

An analysis of the latest research. Significant attention has been devoted to the study of the implementation of innovative methods for managing human resource development in agribusiness enterprises by researchers such as O. Babchynska, V. Gaeva, N. Zingaeva, V. Stilnyk, S. Kucherenko, I. Kot, S. Ostrianina, O. Mokii, D. Drobitko, H. Varina, O. Kovaliova, N. Hudz, I. Sheluzhak, S. Todoriuk, and V. Kifiak. In their works, they emphasize the importance of modernizing approaches to human capital development, introducing e-learning, coaching, gamification, and other innovative tools. However, despite the significant contributions to the advancement of this topic, certain aspects remain insufficiently explored. In particular, further research is needed on the adaptation of innovative methods to the specific features of regional agricultural production, the evaluation of their effectiveness under conditions of seasonality and labor market instability, as well as the development of mechanisms for engaging employees in continuous professional development.

Formulation of the purpose of the study. The aim of the research is to substantiate the theoretical foundations and develop practical recommendations for implementing innovative methods of human resource development management in the activities of enterprises in the agro-industrial complex, considering current trends in digitalization, technological changes, and labor market demands. The research tasks involve identifying the features of using innovative approaches to the formation and development of human capital in the agricultural sector, analyzing existing practices, determining the key factors of effectiveness of innovative management technologies, and formulating recommendations for their integration into the human resources policy of agro-enterprises.

Presentation of the main research. Modern trends in the development of the agro-industrial complex impose new requirements on the human resource management system, which necessitates the implementation of innovative methods for human resource development. The activities of enterprises in the agricultural sector are closely linked to the use of technological innovations, automation of production processes, and digitalization of management procedures. As a result, the role of personnel is also changing. Personnel development management in the context of the agro-industrial complex requires the integration of innovative methods into the overall strategy of enterprise development. The introduction of cutting-edge technologies should be accompanied by changes in organizational

culture aimed at promoting openness to change, fostering initiative, and supporting a creative approach to solving production challenges. Therefore, the improvement of the personnel development system based on innovative approaches becomes a key factor in ensuring the competitiveness of agro-industrial enterprises.

Innovative methods of personnel development management encompass a wide range of tools and technologies aimed at forming new competencies, increasing professional flexibility, developing creative thinking, and enhancing the ability to adapt quickly. Among these methods, E-learning holds a special place, as it enables the organization of qualification improvement processes regardless of spatial and time constraints. This form of training has become popular due to its flexibility and ability to optimize time for both trainers and participants [4]. The E-learning method is a modern and flexible tool for personnel development that can be effectively applied in enterprises within the agro-industrial complex. Thanks to the ability to learn online, employees can gain knowledge at a convenient time without interrupting their main work processes. This is particularly important for the agricultural sector, where the seasonality of work and uneven workloads affect the availability of traditional training. E-learning allows for training using modern platforms that offer a wide range of educational materials: video lectures, interactive modules, webinars, tests, and simulators. For agricultural workers, this can provide an opportunity to study the latest agronomic technologies, plant protection methods, precision farming principles, and the use of drones or other digital tools for field monitoring. For example, agronomists can take courses on soil analysis, while technical staff can learn to maintain modern agricultural machinery. This method also helps improve knowledge in management and economics for company executives. Online courses can cover topics such as financial management, risk management, cost optimization, or agricultural product marketing. Furthermore, E-learning supports professional growth by providing access to the best international practices and expertise from leading specialists. The use of E-learning helps make the learning process accessible and effective, improving personnel qualifications and enhancing the competitiveness of agro-enterprises, while promoting their sustainable development in the modern agricultural market.

An important aspect is that training materials can be tailored to the specifics of the region, taking into account climatic conditions, soil types, and the specifics of growing certain crops in a given area. Another advantage is the ability to organize joint training for employees from different companies, creating a platform for experience exchange. This fosters the formation of a professional community that brings together agricultural producers, agronomists, technical specialists, and managers.

Another important component is the use of gamification in the professional development system, which enhances motivation to learn. Introducing game elements into training programs makes the process of acquiring new knowledge more engaging and interactive, which is especially relevant for younger workers. Thanks to gamification, employees can develop not only professional competencies but also important personal qualities such as teamwork, leadership, and problem-solving skills.

The implementation of adaptive learning based on artificial intelligence opens new perspectives for individualizing the personnel development process. By analyzing data on each employee's learning outcomes, the system can propose personalized professional growth trajectories. This is particularly important for enterprises in the agro-industrial complex, where the qualification level of employees can vary significantly depending on their position, specialization, and work experience.

54-62
v.30 (2025)
https://smart-scm.org

The active use of virtual and augmented reality technologies allows for the modeling of production processes, creating simulators for practicing complex skills without risk to real production. For the agricultural sector, this is especially relevant when working with machinery, complex equipment, or in processes where significant financial or environmental risks exist in case of employee errors.

Innovative approaches to personnel development also include the introduction of the concept of continuous learning, which should become part of the corporate culture of agro-industrial enterprises. The continuous learning system is aimed at regularly updating employees' knowledge and skills, which is critical in the context of rapid technological changes. It is based on principles of self-education, mentoring, participation in professional communities, and the use of external learning resources. Another component of the innovative approach to personnel development is the creation of internal corporate universities, training centers, and innovation laboratories. Such structures allow enterprises to independently form the necessary competencies, quickly respond to market changes, and integrate new developments into production processes. In developed economies, effective approaches to corporate training and enhancing the professional potential of employees are widely used (Fig. 1).

Figure 1 – Innovative Methods of Personnel Development Management [4; 5]

Coaching serves as an effective tool for personnel development, capable of significantly enhancing the productivity of agricultural enterprises. This method is focused on providing individual support to employees, helping to unlock their potential, improve professional competencies, and solve specific tasks in the agricultural sector [6]. Thus, coaching can be used to introduce the latest technologies and practices. For example, mentor-coaches can work with agronomists or technical staff, helping them better understand the benefits and operational principles of modern tools, such as drones for field monitoring, precision farming systems, or automated irrigation complexes. Instead of simple instruction, coaching focuses on a personalized approach, supporting employees in applying these technologies to meet the real needs of their enterprises. For the management staff of agricultural enterprises, coaching becomes an effective tool for developing leadership skills. Middle and senior managers can learn to make more effective decisions, motivate teams, and optimize work processes. This is particularly important in agriculture, where there is often a need to quickly adapt to changes – whether due to weather conditions or market fluctuations. Coaching is also useful for adapting new employees, especially young ones starting their careers in agriculture. Individual work with a coach helps newcomers not only quickly acquire basic skills but also build trust with their team, understand the specifics of the job, and adopt

the corporate culture of the enterprise. In addition, this method can be used to address specific problems. For example, coaches can help employees solve issues related to cost optimization, increasing yields, pest control, or mastering new agricultural technologies. Coaching encourages the search for personal solutions, develops critical thinking, and boosts confidence in one's actions. In the context of Ukrainian agrarians, where agriculture has rich traditions but faces modern challenges, coaching will help enterprises combine traditional knowledge with innovative approaches. This will contribute to increased productivity, staff motivation, and ensure the sustainable development of the agro-industrial sector.

Buddying is the process of knowledge and experience transfer between individuals, based on the principles of interaction and feedback. The essence of this method lies in informal knowledge exchange between professionals who are willing to share their experience based on mutual interest. It does not imply a strict structure or rigid regulations, such as set hours or mandatory meetings [4]. On the contrary, the exchange happens spontaneously, often in an informal setting, between colleagues who share common interests or work on similar tasks. The buddying method can also be an effective tool for personnel development in agricultural enterprises, considering the specifics of a particular region and the characteristics of the industry. In agriculture, there is often a gap between the experience of senior professionals and the needs of younger workers, as well as between traditional practices and modern technologies actively being implemented in the agricultural sector. Buddying helps to bridge these resources, creating an environment for continuous learning. Experienced workers, familiar with the climatic and soil conditions of a specific region, can pass on their knowledge to younger agronomists or workers, helping to adapt modern technologies to local conditions. For example, they can explain which crop varieties are better suited to different areas, how to use fertilizers more effectively, or how to optimize work depending on weather conditions. Additionally, younger specialists with knowledge of the latest agricultural techniques, such as using GPS navigation, drones for field monitoring, or digital management systems, can share these insights with senior colleagues. This facilitates the integration of modern technologies into traditional processes. Buddying can also be used to organize informal knowledge exchanges between agricultural producers working in the same region. Such meetings can help spread best practices in crop growing, pest control, or cost optimization, contributing to the overall development of the region's agricultural sector. To enhance qualification at the workplace, new employees can be paired with experienced mentors who will teach them the nuances of specific tasks, such as operating machinery, caring for livestock, or working with irrigation systems, in an informal setting. This approach will help newcomers adapt more quickly to the working conditions and requirements of the enterprise. Buddying will also help form a corporate culture by fostering an atmosphere of mutual assistance and trust within the team. In agriculture, where work is often collaborative, this is especially important. The implementation of buddying will allow agricultural enterprises to create a flexible learning system based on human interactions, which will foster professional development, improve productivity, and enhance the competitiveness of the region's agricultural sector.

The Shadowing method is a form of training where an employee "shadowing" observes an experienced colleague's work [5]. This method can be extremely useful in personnel development at agro-industrial enterprises, as it allows new or less experienced employees to learn from real-life work examples and gain practical knowledge directly in the field, observing the work of more experienced colleagues. This method is

particularly effective in agriculture, where knowledge is often transferred through hands-on experience. Employees who shadow their mentors have the opportunity to master various aspects of the work, from organizing agricultural processes to servicing machinery and managing workgroups. For example, young agronomists or technicians may observe the work of more experienced colleagues, learning best practices in crop growing, land preparation, or even setting up and maintaining agricultural machinery. This will allow them to quickly acquire necessary skills and knowledge without the need for prolonged theoretical training, as practical experience is often the most effective. For managers or employees seeking to develop their leadership and management skills, the Shadowing method also offers the opportunity to learn from real-life examples of decision-making, staff interaction, and solving work-related issues. This approach will allow junior managers or future company leaders to better understand corporate culture and effective management strategies by observing the work of more experienced colleagues. This method also facilitates a faster integration of new employees into the work process, allowing them to directly engage with the enterprise's activities and receive valuable advice and feedback from those who already have experience. As a result, the Shadowing method not only enhances employees' qualifications but also helps them adapt to the specific nature of work in the agricultural sector, which is crucial for the development of agro-industrial enterprises.

Another interesting method is Secondment, which involves transferring staff to another department or even enterprise to gain specific experience [4]. This method can also be used to exchange experience between different enterprises in the agricultural sector. It will allow employees to learn how to use innovative approaches and effective strategies. Temporary transfers provide employees with new career growth and development opportunities, as they allow them to demonstrate their abilities in new roles or positions. Through Secondment, employees can gain important interdisciplinary experience, which will later contribute to more efficient performance in their main roles. For the enterprise, it is also an opportunity to bring in new ideas and approaches, improve management and technologies, thereby enhancing the overall efficiency of the enterprise.

After analyzing various methods aimed at managing personnel development, we suggest that agro-industrial enterprises, in addition to the aforementioned methods, focus on developing their personnel in the directions depicted in Figure 2.

An important condition for the effective implementation of innovative methods for managing personnel development is the formation of a system for evaluating training outcomes. This will allow for tracking the dynamics of changes in employees' professional training, assessing the impact of educational activities on production performance, and adjusting development programs according to the actual needs of the enterprise.

Equally important is the involvement of employees in the process of developing and improving training programs. Active participation in identifying their educational needs, assessing the quality of training, and suggesting improvements to training programs will increase their motivation and engagement in their own development process.

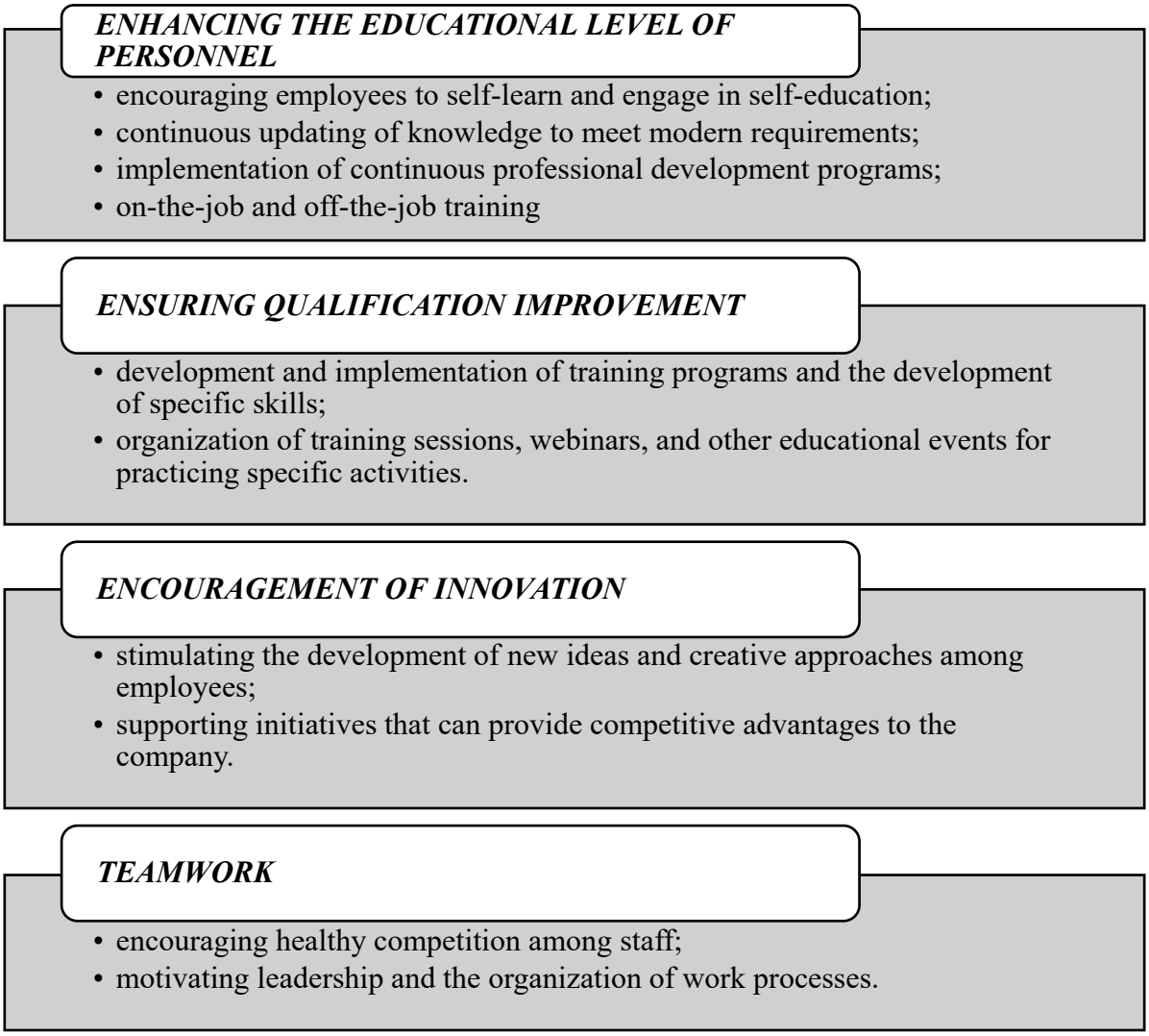

Figure 2 – Directions of personnel development in agro-industrial enterprises [1; 2; 3]

Thus, the implementation of innovative methods for managing personnel development in agro-industrial enterprises is a key factor in their competitiveness in the context of the digital economy. Innovative technologies open up broad opportunities for enhancing employee qualifications, forming new competencies, and stimulating their activity and creative potential, which are crucial for the successful development of agricultural production in the future.

Conclusions. The conducted research has demonstrated that innovative methods of managing personnel development are a key factor in enhancing the competitiveness of enterprises in the agro-industrial sector amid digitalization and technological change. The relevance of integrating such methods is driven by the need for rapid adaptation to labor market dynamics, the growing importance of highly qualified personnel, and the necessity of implementing advanced agricultural technologies.

The proposed innovative approaches – including e-learning, gamification, adaptive learning, the use of virtual and augmented reality technologies, buddying, shadowing, and coaching – have proven effective in developing professional competencies, fostering initiative, creativity, and readiness for change. Particularly important is the implementation of continuous learning and the creation of internal corporate educational platforms, which will contribute to sustainable professional development of personnel.

The practical implementation of the proposed methods will enable agricultural

enterprises to introduce technological innovations more quickly, optimize production processes, increase labor productivity, and reduce costs. Furthermore, innovative approaches will promote the formation of a favorable environment for knowledge exchange, the development of teamwork, and the enhancement of overall employee motivation.

Therefore, the application of innovative personnel development methods should become a strategic priority for agricultural enterprises aiming for sustainable growth and effective response to the challenges of the modern agricultural market.

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CONCEPTUAL FOUNDATIONS FOR SHAPING AND TRANSFORMING ORGANIZATIONAL CULTURE IN AVIATION ENTERPRISES THROUGH THE LENS OF SUSTAINABLE DEVELOPMENT GOALS AND THEIR STRATEGIC RELEVANCE

Mykhailo Podrieza. «Conceptual foundations for shaping and transforming organizational culture in aviation enterprises through the lens of sustainable development goals and their strategic relevance». *This article explores the conceptual foundations for shaping and transforming organizational culture in aviation enterprises within the framework of the United Nations Sustainable Development Goals (SDGs). The study emphasizes the strategic relevance of aligning internal cultural transformations with economic, social, and environmental goals to enhance long-term competitiveness and resilience. Particular attention is given to the integration of SDG-driven values into corporate culture, the development of adaptive management practices, and the role of organizational maturity in accelerating sustainable transformation. By examining the interconnection between cultural dynamics and sustainable development imperatives, the research provides insights into how aviation enterprises can evolve into socially responsible and ecologically conscious actors in the post-crisis global economy.*

Keywords*:* organizational culture, aviation enterprises, sustainable development, Sustainable Development Goals (SDGs), transformation, competitiveness, organizational maturity, corporate values, management practices, environmental responsibility

Михайло Подрєза. «Концептуальні основи формування та трансформації організаційної культури авіаційних підприємств крізь призму цілей сталого розвитку та їхньої стратегічної актуальності». *У статті досліджуються концептуальні засади формування та трансформації організаційної культури на авіаційних підприємствах у контексті Цілей сталого розвитку ООН (ЦСР). Акцент зроблено на стратегічній важливості узгодження внутрішніх культурних змін із економічними, соціальними та екологічними орієнтирами для забезпечення довгострокової конкурентоспроможності та стійкості. Особлива увага приділяється інтеграції цінностей, заснованих на ЦСР, у організаційну культуру, розвитку адаптивних управлінських практик, а також ролі організаційної зрілості у прискоренні переходу до сталого розвитку. Робота розкриває взаємозв'язок між культурною динамікою та імперативами сталого розвитку, пропонуючи бачення того, як авіаційні підприємства можуть трансформуватись у соціально відповідальних і екологічно свідомих учасників ринку у посткризовий період.*

Ключові слова: організаційна культура, авіаційні підприємства, сталий розвиток, цілі сталого розвитку, трансформація, конкурентоспроможність, організаційна зрілість, корпоративні цінності, управлінські практики, екологічна відповідальність.

Intraduction. Organizational culture is frequently characterized as a set of shared beliefs, norms, and values that influence employees' behavior and decision-making. However, when it comes to the education of future managers, corporate culture should be viewed not only as a reflection of a company's personality—shaped by its history, vision, people, and working environment—but also as a pedagogical construct that can be intentionally developed and embedded into professional training programs.

Modern management education should not be limited to transferring technical knowledge and analytical tools. It must also cultivate value-based leadership, ethical decision-making, and a deep understanding of organizational dynamics. Incorporating the concept of corporate culture into the curriculum contributes to developing students' professional identity and moral responsibility, while also preparing them to foster healthy, inclusive, and high-performing organizational environments.

Materials and Methods. This study employs a mixed-methods approach, combining both qualitative and quantitative research techniques to explore the formation and transformation of organizational culture in aviation enterprises, particularly in the post-war context and through the lens of sustainable development.

The qualitative part of the research involved expert interviews with representatives from management and HR departments of Ukrainian aviation enterprises, as well as content analysis of corporate documents (e.g., mission statements, CSR reports, codes of ethics). These materials were analyzed to identify dominant cultural patterns, values, and orientation toward the Sustainable Development Goals (SDGs), especially the social and environmental components.

For the quantitative part, a structured questionnaire was developed to assess the current type and maturity level of organizational culture based on Denison's organizational culture model. The survey included indicators aligned with DEI&B (Diversity, Equity, Inclusion, and Belonging), ecological responsibility, and strategic flexibility. Respondents included middle and top managers from selected aviation companies, with a total sample size of 150 participants.

The data obtained were processed using correlation-regression analysis to determine the relationship between cultural attributes and key performance indicators, such as profitability, environmental investment ratios, and employee engagement metrics. SWOT analysis was also applied to identify strengths, weaknesses, opportunities, and threats in the organizational culture context of the industry.

This methodological approach allows for a holistic understanding of how cultural transformation can serve as a lever for sustainable growth and resilience in the aviation sector.

Presentation of the main research. Research shows that corporate culture significantly influences company performance, sustainability, and adaptability. In a survey conducted by Duke's Fuqua School of Business among 1,800 global executives, 78% identified culture as one of the top five factors determining organizational value, and 92% believed that strengthening culture would increase their company's worth. These insights underline the importance of equipping future managers with the competence to both assess and shape culture in the organizations they will serve.

In the educational context, the key elements of corporate culture—vision, values, behaviors, storytelling, leadership

style, and environment—should be translated into teaching models, case studies, and experiential learning opportunities. Students must be exposed to the complexities of aligning individual values with organizational goals, and to the mechanisms by which corporate culture influences team dynamics, communication, conflict resolution, and innovation.

Leadership training should emphasize the development of so-called "culture carriers"—individuals who act as agents of ethical and strategic transformation within organizations. This includes fostering the ability to build trust, facilitate collaboration, and lead with empathy and integrity. Within classrooms, these skills can be nurtured through reflective practices, simulations, real-world consulting projects, and analysis of both successful and dysfunctional corporate cultures.

The integration of storytelling and narrative in the educational process plays a critical role in forming cultural awareness. By studying how organizational legends, rituals, and routines are constructed and maintained, students gain insights into the symbolic layer of culture and its role in reinforcing organizational norms. These dimensions are essential for preparing managers who are not only strategic thinkers but also capable of managing meaning and purpose within their teams.

Furthermore, the physical and social environment of learning should support a culture of openness, mutual respect, and continuous dialogue. Universities and business schools must model the type of culture they aim to instill—where feedback is encouraged, diversity is valued, and leadership potential is recognized early and developed systematically. In conclusion, embedding organizational culture into the education of future managers is not merely an academic exercise but a strategic imperative. It enables the formation of professionals who are conscious of their role in shaping responsible, resilient, and value-driven organizations. Pedagogical strategies that intentionally integrate culture into management training will contribute to the long-term sustainability of enterprises and the ethical maturity of those who lead them.

Organizational culture can be understood as a collective system of values and beliefs that shape how employees behave and interact within an organization. It is also useful to perceive corporate culture as the organization's "personality"—a synthesis of its historical background, strategic vision, personnel, and working environment.

According to a study by Duke University's Fuqua School of Business, which surveyed 1,800 global CEOs and CFOs, 78% identified corporate culture as one of the top five elements influencing overall company value.[2] Moreover, 92% of respondents agreed that enhancing corporate culture would lead to an increase in company value. Whether an organization is focused on fostering a high-performance culture or working to improve existing cultural traits, it is evident that culture plays a crucial role in determining business success.[1]

To effectively navigate and influence corporate culture, it is important to first grasp its fundamental components. At its core lies the organization's purpose and vision—elements that define its long-term direction and competitiveness. These are supported by core values, which establish the expected attitudes and behaviors necessary to fulfill the organizational mission. Vision and values together provide a blueprint for leadership, communication, and employee conduct.

While some values may represent future aspirations, others already characterize the current corporate environment. For instance, a tech firm might aim to achieve zero-defect performance (aspirational) while already being known for its innovation (established value). As organizations evolve, periodic reassessment of their vision and values is essential to ensure alignment with new challenges and growth stages. Regardless of changes, clarity and communication of these core elements to all employees is critical.

Employees themselves are perhaps the most defining factor of corporate culture. As primary "culture bearers," their behaviors and interactions are central to how clients, potential recruits, and stakeholders perceive the organization. For this reason, targeted employee training can be instrumental in promoting behavior that reinforces desired cultural traits. These behaviors may stem from inherent qualities or be developed through learning, and may include leadership practices, feedback mechanisms, interpersonal dynamics, and collaboration methods.

Each company also has its own unique narrative, which becomes embedded in its culture over time. Recurrent storytelling practices—such as celebrating key achievements, organizing routine rituals, or commemorating important milestones—reinforce organizational identity and shared values.[3]

Physical and social work environments also have a considerable impact on cultural development. Regional factors, such as the innovation-driven ecosystem of Silicon Valley, or workplace design—like open-plan spaces encouraging teamwork—can both influence cultural dynamics. In industries like finance, the high-intensity atmosphere of trading floors can cultivate a fast-paced, vocal culture.

Although the definition of corporate culture can vary, its essence lies in the guiding vision and values that shape how individuals act and think. Every aspect of the culture is influenced by strategic decisions and leadership actions. Cultivating a preferred culture involves a combination of behavior-driven initiatives and structural changes. In some cases, a comprehensive cultural transformation may be necessary to align with broader organizational objectives and long-term growth.

To build a truly resilient and adaptive corporate culture, organizations must also consider the dynamic external environment in which they operate. This includes market volatility, technological advancements, global competition, and socio-political shifts—all of which can pressure an organization to change more quickly and deliberately. In such contexts, corporate culture becomes both a stabilizing force and a strategic differentiator. It's not only about shared beliefs or behaviors but about fostering agility, learning, and innovation at all levels of the organization. Companies that succeed in embedding a learning-oriented culture are often more capable of sustaining long-term competitive advantages, particularly during periods of transformation or disruption.

Leadership plays a crucial role in cultivating and sustaining such a culture. Ethical and inclusive leadership that models transparency, accountability, and empathy strengthens trust and cohesion within teams. Leaders who champion continuous learning and open dialogue inspire employees to embrace change and align their efforts with the organization's strategic direction. When leaders are deliberate in their actions and communication, they reinforce cultural values and ensure consistency between stated ideals and actual behavior. Over time, this consistency shapes how people interpret their work and purpose within the company, creating a more engaged and motivated workforce.

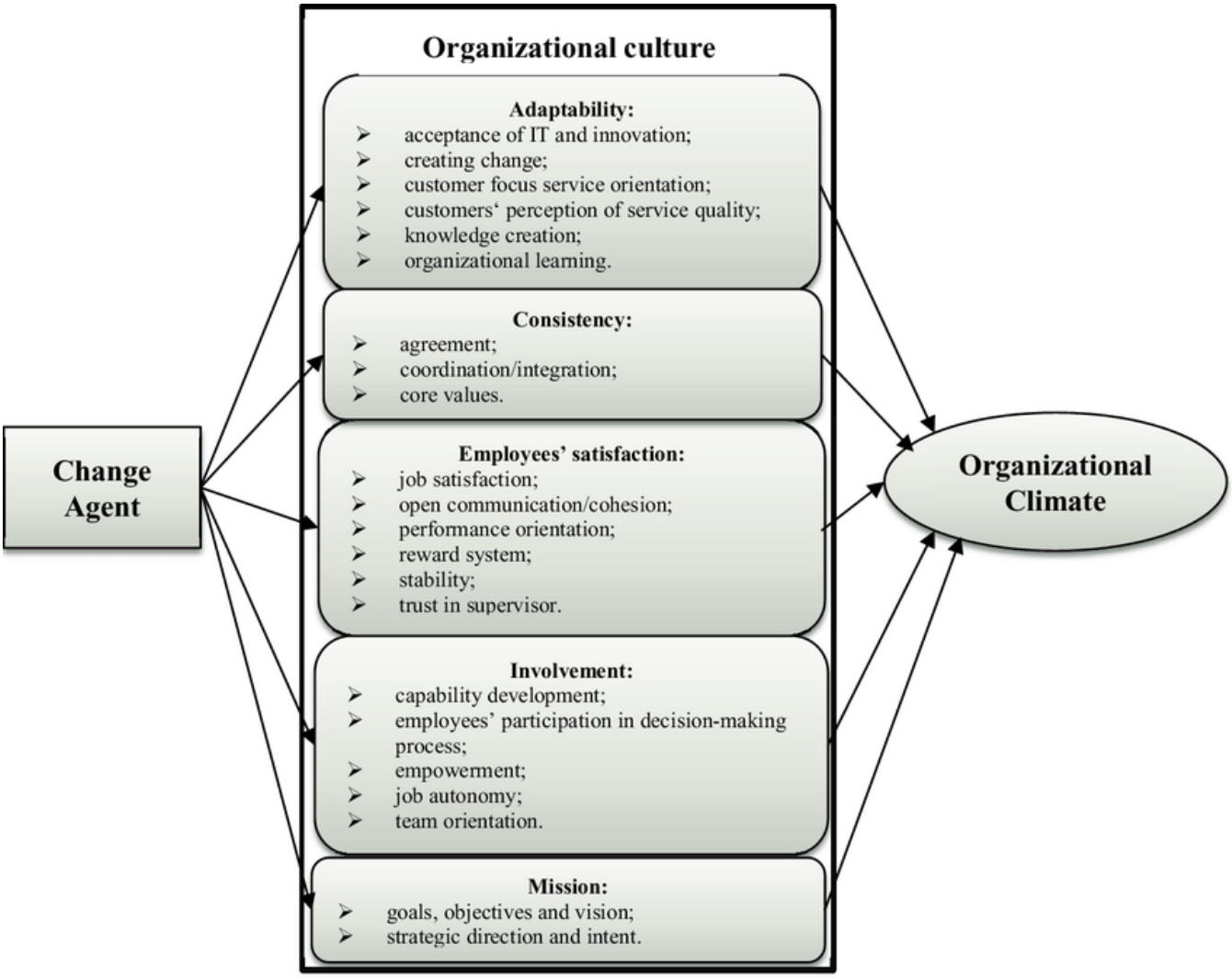

Figure 1 – Theoretical model: Organizational culture factors influencing organizational climate [5]

Another vital aspect of sustaining corporate culture lies in embedding it into systems and processes. Recruitment practices, performance evaluations, recognition programs, and career development pathways should all reflect the organization's core values and desired behaviors. For example, hiring for cultural fit—while remaining open to diversity of thought—ensures that new employees align with the company's mission while bringing fresh perspectives. Similarly, reward systems that emphasize collaboration, innovation, or service excellence can help reinforce cultural expectations and drive desired outcomes.

Organizational culture is not static; it evolves with the organization's growth, strategy, and people. To remain effective, culture must be intentionally reviewed and recalibrated. Periodic assessments, employee feedback mechanisms, and leadership retreats offer opportunities to evaluate cultural health and diagnose misalignments. During major transitions—such as mergers, leadership changes, or shifts in business models—these evaluations are especially important to ensure that cultural identity is not lost but rather strengthened in ways that support new objectives.

In today's business landscape, where adaptability and sustainability are paramount, corporate culture is no longer a soft issue relegated to HR departments. It is a strategic asset that can determine an organization's capacity to innovate, attract and retain talent, and deliver long-term value.

Companies that consciously design and nurture their cultures—anchored in vision and values, supported by leadership and systems, and responsive to internal and external shifts—are better positioned to thrive in the complexity of the modern world.

This evolving nature of corporate culture is especially critical in industries undergoing rapid transformation or facing existential challenges—such as the aviation sector. Aviation enterprises today must navigate not only market competitiveness and technological disruption but also increasing pressure to meet sustainability goals, ensure passenger safety, and comply with stringent regulatory frameworks. In such a high-stakes environment, a strong, adaptive corporate culture can serve as both a compass and a catalyst for innovation and resilience.

For aviation companies, cultural alignment around core values such as safety, precision, accountability, and customer focus is non-negotiable. Yet as these companies respond to global calls for greener operations and more inclusive workplaces, their cultures must also expand to encompass values like environmental stewardship, cross-cultural collaboration, and ethical governance.[7] This expansion requires deliberate cultural leadership—a type of leadership that is attuned not only to operational performance but to the organizational ecosystem as a whole, including the well-being and empowerment of its workforce.

Figure 2 – Organizational culture and communication [6]

Furthermore, in post-crisis or high-uncertainty scenarios—such as recovery from global pandemics, economic downturns, or military conflict—aviation enterprises are particularly reliant on their organizational culture to rebuild stability and trust. Cultural resilience, in this context, becomes a strategic imperative. It is what enables teams to stay cohesive under pressure, align around evolving goals, and maintain high standards despite external shocks. Organizations with mature cultures are better able to sustain morale, retain critical talent, and pivot operations to address new realities without compromising their core identity.

Culture also has a direct link to the development and sustainability of human capital, which is increasingly viewed as a central pillar of competitive advantage in knowledge-based industries like aviation. A culture that values continuous learning, professional growth, and inclusive decision-making not only attracts high-caliber talent but also encourages retention and engagement. Moreover, when employees feel seen, valued, and included in shaping the organization's future, their intrinsic motivation rises, leading to improved performance and innovation across departments.

From a strategic perspective, then, corporate culture must be intentionally integrated into every facet of the organization—from long-term vision setting to day-to-day operations. It must be measured, cultivated, and, when necessary, transformed. Successful aviation enterprises are already embedding cultural metrics into performance dashboards, using culture as a lens to assess risk and opportunity, and training leaders to become active stewards of the cultural journey.

In conclusion, the strategic management of corporate culture is not merely a leadership preference—it is a critical determinant of enterprise success. For aviation companies facing multifaceted global pressures, the ability to shape, evolve, and align culture with organizational purpose and external demands is essential. It's through this cultural agility that organizations will secure both operational excellence and long-term sustainability in an ever-changing world.

This cultural agility also serves as the foundation for organizational learning and continuous improvement—two factors that are indispensable in the aviation industry, where safety margins are tight, technological cycles are short, and regulatory expectations are high. An adaptive culture that promotes psychological safety, open communication, and knowledge-sharing empowers employees to report errors, suggest improvements, and challenge outdated processes without fear of retribution. These behaviors are critical not only for preventing accidents but also for nurturing a proactive mindset that anticipates problems and innovates solutions.

Equally important is the alignment of corporate culture with broader global movements such as the UN Sustainable Development Goals (SDGs). Aviation companies increasingly find themselves under scrutiny for their environmental impact, social practices, and governance standards. A mature and values-driven culture enables these organizations to integrate ESG principles not as compliance obligations, but as intrinsic elements of their corporate identity. For example, when sustainability becomes a lived value—rather than just a slogan—employees are more likely to contribute to green innovation, whether through fuel efficiency, waste reduction, or digital transformation efforts.

Leadership plays a pivotal role in this cultural evolution. Leaders must go beyond articulating values; they must embody them through consistent action, transparent communication, and inclusive decision-making. In aviation, where hierarchical structures often dominate, the shift toward more participatory, ethical leadership can redefine how authority and accountability are exercised. Leaders who engage authentically with their teams and who understand the nuanced experiences of frontline employees can more effectively steward change and build trust.

The role of storytelling and symbolic actions in shaping culture should not be underestimated either. Aviation enterprises, many of which have long and storied histories, can harness their legacy as a source of cultural strength. Commemorating past achievements, honoring employees' contributions, and articulating a compelling vision for the future can create a strong sense of belonging and continuity even in times of disruption. These cultural rituals reinforce shared identity and purpose, essential ingredients for resilience and cohesion.

Conclusions. Finally, the measurement and reinforcement of cultural outcomes are key to sustaining progress. Organizations must invest in tools and frameworks that assess cultural health, track behavior alignment with values, and identify gaps between aspirational culture and lived experience. Regular culture audits, employee surveys, and feedback loops provide actionable insights that inform strategy and leadership development. When culture is treated with the same rigor as financial performance or operational metrics, it becomes a true lever of strategic advantage.

In essence, organizational culture in aviation is not a peripheral concern—it is the infrastructure that underpins safety, innovation, sustainability, and human capital development. As the industry confronts unprecedented challenges and redefines its role in a complex, interconnected world, those organizations that prioritize cultural integrity and adaptability will be the ones best positioned for enduring success.

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EFFICIENCY OF AIR TRANSPORT IN INTEGRATED LOGISTICS SYSTEMS

Irina Suvorova, Oksana Pozniak, Kashlakova Tetiana «Efficiency of Air Transport in Integrated Logistics Systems». *The article examines the role and efficiency of air transport within integrated logistics systems, emphasizing its strategic function in ensuring speed, reliability, and global connectivity in multimodal supply chains. Air transport is positioned as a critical component that facilitates rapid movement of time-sensitive and high-value goods, particularly in sectors such as pharmaceuticals, electronics, and e-commerce. The article identifies and analyses the core advantages of air freight, including short delivery times, high schedule predictability, secure handling, and the ability to serve geographically isolated regions. In addition to highlighting these strengths, the study also outlines the main limitations of air transport, such as high operational costs, limited cargo capacity, infrastructure dependency, environmental concerns, and strict regulatory requirements. Special attention in the article is given to the integration of digital technologies and the application of the AeroSync model as an innovative conceptual framework aimed at improving operational efficiency and supporting decision-making in air logistics. The model systematizes key components of the logistics process–input factors, constraints, integration mechanisms, and performance outcomes–and serves as a scalable and versatile tool for logistics companies seeking to optimize multimodal transportation involving air freight. The study includes an in-depth analysis of real-world implementation practices by leading*

71-81
v.30 (2025)
https://smart-scm.org

international logistics firms such as SEKO Logistics, Omni Logistics, Noatum Logistics, and Logistics Plus. These case studies illustrate the effectiveness of combining air transport with digital platforms, analytical tools, and strategic planning to achieve higher levels of control, adaptability, and competitiveness in a global logistics environment. The findings confirm that air transport, despite its challenges, remains indispensable in modern global logistics and that its performance can be significantly enhanced through structured integration models and smart technology adoption.

***Keywords**:* air transport, logistics systems, multimodal transportation, efficiency, digitalization, AeroSync model, supply chains

Ірина Суворова, Оксана Позняк, Кашлакова Тетяна «Ефективність авіаційного транспорту в інтегрованих логістичних системах». *У статті розглядається роль та ефективність авіаційного транспорту в інтегрованих логістичних системах, з акцентом на його стратегічну функцію забезпечення швидкості, надійності та глобальної зв'язності в умовах мультимодальних ланцюгів постачання. Авіаперевезення позиціонуються як ключовий компонент, що забезпечує оперативне переміщення термінових і цінних вантажів, особливо в таких галузях, як фармацевтика, електроніка та електронна комерція. У статті визначено та проаналізовано основні переваги авіаційного транспорту, зокрема: короткі терміни доставки, висока передбачуваність графіків, безпечна обробка вантажів та здатність обслуговувати географічно ізольовані регіони. Окрім висвітлення сильних сторін, дослідження також окреслює основні обмеження авіаперевезень, серед яких: високі експлуатаційні витрати, обмежена вантажомісткість, залежність від інфраструктури, екологічні виклики та жорстке нормативне регулювання. Особливу увагу в статті приділено інтеграції цифрових технологій і застосуванню моделі AeroSync як інноваційної концептуальної основи, спрямованої на підвищення операційної ефективності та підтримку процесів прийняття рішень в авіаційній логістиці. Модель систематизує ключові компоненти логістичного процесу – вхідні фактори, обмеження, механізми інтеграції та результати – і виступає масштабованим та універсальним інструментом для логістичних компаній, які прагнуть оптимізувати мультимодальні перевезення із залученням авіатранспорту. У дослідженні представлено глибокий аналіз практик впровадження моделі у діяльність провідних міжнародних логістичних компаній, зокрема SEKO Logistics, Omni Logistics, Noatum Logistics та Logistics Plus, ці кейси ілюструють ефективність поєднання авіаперевезень із цифровими платформами, аналітичними інструментами та стратегічним плануванням для досягнення вищого рівня керованості, адаптивності та конкурентоспроможності у глобальному логістичному середовищі. Отримані результати підтверджують, що, попри існуючі виклики, авіаційний транспорт залишається незамінним елементом сучасної глобальної логістики, а його ефективність може бути суттєво підвищена завдяки впровадженню структурованих моделей інтеграції та інтелектуальних технологічних рішень.*

Ключові слова: авіаційний транспорт, логістичні системи, мультимодальні перевезення, ефективність, цифровізація, модель AeroSync, ланцюги постачання.

Intraduction. In today's world, characterized by rapid globalization, growing international competition, and the accelerated development of digital technologies, logistics plays a crucial role in ensuring the effective functioning of the global economy. Particular attention must be paid to improving logistics systems capable of providing fast, secure, and reliable cargo movement on a global scale. Amid the growing volumes of international trade, increasingly complex supply chains, and rising consumer expectations for speed and service quality, there is a pressing need to

explore new approaches to organizing logistics processes. One such direction involves the integration of various modes of transport within a unified logistics system, which enhances flexibility, optimizes costs, and ensures timely delivery. In this context, there is a growing need for a comprehensive scientific analysis of the efficiency of individual links in the logistics chain– especially the transport component, which plays a critical role in maintaining the continuity of goods flow. Given these considerations, the topic of transport efficiency in integrated logistics systems is highly relevant and requires in-depth investigation that takes into account modern challenges, trends, and technological advancements.

Analysis of the latest research and publications. In contemporary academic and applied literature, increasing attention is being paid to enhancing the efficiency of air transport within integrated logistics systems. Ukrainian researchers Krawets O.M. and Shevchenko O.V. emphasize the integration of marketing and logistics approaches to improve the competitiveness of enterprises operating in global supply chains [1]. Obruch H.V. and Sotnikov D.V. explore the role of strategic logistics management in the context of digital transformation, highlighting the need for comprehensive models of interaction among transportation components, including aviation [2]. Foreign scholars Chopra and Meindl consider air transport a critical element in the effective functioning of supply chains, especially in terms of strategy and planning [3], while Rushton, Croucher, and Baker focus on practical aspects of distribution management and the selection of optimal transport modes depending on logistics objectives [4].

Particular attention in this field is given to the report of the Intergovernmental Panel on Climate Change regarding the environmental impact of aviation [5], which underscores the necessity to evaluate transport efficiency not only from an economic but also from an ecological standpoint. Relevant approaches to digital transformation in airline logistics are presented in the work of Moghadasnian S., which examines the use of artificial intelligence and blockchain technologies to improve operational performance [6]. Ukrainian researchers Poberezhna Z., Petrova Y., and Slimani K. analyze the implementation of information technologies in the logistics processes of aviation enterprises, emphasizing the adaptation of organizations to modern digital challenges [7]. Additionally, the study by Chenyu Li [8] on the development of air logistics in cross-border e-commerce is highly relevant amid growing international cargo flows. Regular reports by IATA [9] and the World Bank [10] offer deep analytics of the air cargo market and global logistics efficiency, providing a solid analytical foundation for further research.

Objectives statement. The issue of efficient use of air transport in integrated logistics systems arises from the need to consider its specific advantages and limitations in multimodal transportation. The objective of this study is to systematize the key factors influencing the appropriateness of involving air freight, to define the conditions for its optimal functioning, and to analyze the role of digital solutions–particularly the AeroSync model–in ensuring speed, reliability, and coordination of logistics processes.

Basic material and results. Integrated logistics systems (multimodal transportation) involve the use of multiple modes of transport within a single logistics chain to ensure an optimal balance between speed, cost, and reliability [1]. Each mode of transport serves its own function: maritime transport is used for large volumes, rail transport for medium distances, road transport for the «last mile» and air transport for fast delivery over long distances.

Air transport plays a critical role in modern multimodal logistics systems due to several key advantages that distinguish it from other modes of transportation, namely:

1) offers exceptional speed, with delivery times ranging from 12 to 48 hours for

intercontinental shipments. This rapid transit capability is particularly valuable in sectors where time is a decisive factor – such as pharmaceutical logistics, electronics, and high-value goods;

2) ensures reliability. Regular flight schedules and minimal delays contribute to a high level of consistency in deliveries, which is essential for maintaining the integrity of synchronized logistics chains and fulfilling just-in-time strategies;

3) provides global accessibility, enabling companies to reach geographically isolated or infrastructure-poor regions with relative ease. This makes air transport indispensable for connecting emerging markets and supporting global supply chain expansion [5].

Collectively, these attributes position aviation as a strategic pillar within integrated logistics systems, especially in an era marked by the explosive growth of e-commerce and the rising expectations of consumers for faster, more dependable delivery services.

One of the key advantages of air transport in integrated logistics systems is its ability to meet the specific demands of the modern market – from rapid response to ensuring global reach. Compared to other modes of transport, aviation offers unique logistical benefits that are particularly relevant in the context of growing e-commerce, shortened delivery times, and increased requirements for cargo security. Table 1 presents a structured overview of the main advantages of air transport, complemented by brief descriptions and real-world examples of their practical application in logistics processes.

The outlined advantages of air transport not only underscore its functional significance within integrated and multimodal logistics systems but also highlight its growing strategic role in addressing the complex challenges of the global economy. In an era defined by digital transformation, increased customer expectations, heightened competition, and the demand for resilient and agile logistics solutions, air transport emerges as more than just a mode of delivery — it becomes a critical enabler of business continuity, market responsiveness, and global brand positioning. Its unparalleled speed and reliability offer a competitive edge in sectors where time sensitivity and supply chain precision are paramount. Moreover, the ability of air cargo to maintain stable schedules despite environmental and infrastructural uncertainties enhances the predictability of operations, which is vital for industries dependent on just-in-time logistics. The high security standards inherent to air freight also provide added value for the transport of high-value, sensitive, or perishable goods. Global accessibility further supports the development of international trade relations, while rapid delivery capabilities contribute to customer satisfaction and reinforce a company's reputation as an innovative and dependable service provider. As shown in Table 1, these advantages are not merely theoretical but are widely implemented by leading logistics operators and brands worldwide, confirming the integral role of air transport in shaping the future of global supply chains.

Table 1 – Key advantages of air transport in integrated logistics systems

No.	Advantage	Expanded Description	Practical Application Examples
1.	Speed and Urgency	Air transport provides the shortest delivery times, which is critical for perishable, urgent, or high-value cargo. Fast delivery increases overall logistics efficiency and reduces storage costs.	Fresh flowers from the Netherlands can be delivered to Japan within 12–24 hours. Amazon, FedEx, and UPS use air freight to enable two-day delivery in the e-commerce sector.
2.	Reliability and Predictability	Air freight is less dependent on weather conditions, infrastructure state, or traffic congestion, ensuring schedule stability. High flight frequency enables accurate supply chain planning.	DHL Express guarantees next-day document delivery across Europe. Qatar Airways Cargo and Emirates SkyCargo are also known for their high punctuality of cargo flights.

71-81
v.30 (2025)
https://smart-scm.org

3.	High Level of Security	Strict cargo handling procedures, guarded terminals, and minimal transhipments make air transport ideal for valuable and sensitive goods.	Lufthansa Cargo transports pharmaceuticals using temperature-controlled containers. Specialized certified packaging is used for jewelry and electronics by companies such as Brinks and UPS Capital.
4.	Global Accessibility	Air transport connects even the most remote regions of the world, supporting export growth and international trade. Access to a global network of airports ensures broad market coverage.	Export of microchips from Taiwan to the USA or South Korea, delivery of medical equipment from Germany to African countries, transportation of luxury goods (Chanel, Louis Vuitton) to the Middle East and North America.
5.	Marketing and Brand Value	Fast and reliable delivery enhances customer experience, increases satisfaction, and strengthens the brand's reputation as a responsive and innovative supplier.	Apple uses air freight to deliver new iPhones to over 30 countries on launch day. Zara and H&M use air transport to quickly restock new collections in select global stores.

Source: compiled by the authors

Despite its significant advantages, air transport is subject to a number of objective limitations that substantially affect its efficiency within integrated logistics systems. These constraints arise from both technical and economic factors–such as high operational costs and limited cargo capacity–as well as external conditions, including dependence on infrastructure, weather variability, and international regulatory frameworks. To comprehensively assess the appropriateness of using air freight in logistics, it is essential to consider not only its strengths but also the potential risks, limitations, and operational barriers. Figure 1 presents a structured overview of the main limiting factors that reduce the economic viability and operational resilience of air transportation in today's global environment.

The figure summarizes the main challenges of using air transport in integrated logistics systems. Despite its speed and reliability, air freight is constrained by high operational costs, limited cargo capacity, infrastructure requirements, weather-related disruptions, environmental concerns, and complex regulatory frameworks. These limitations highlight the importance of balanced multimodal strategies and the adoption of innovative solutions to ensure sustainable and efficient logistics performance.

In today's world, where global supply chains are becoming increasingly complex, the need for greater transparency in logistics processes is growing rapidly. Digital platforms play a crucial role in this context, as they enable real-time tracking of cargo movements, control over critical transportation stages, and timely response to deviations from planned routes. This is especially important in air logistics, where delivery time and schedule precision are often the key factors determining efficiency, particularly when handling high-value or time-sensitive shipments.

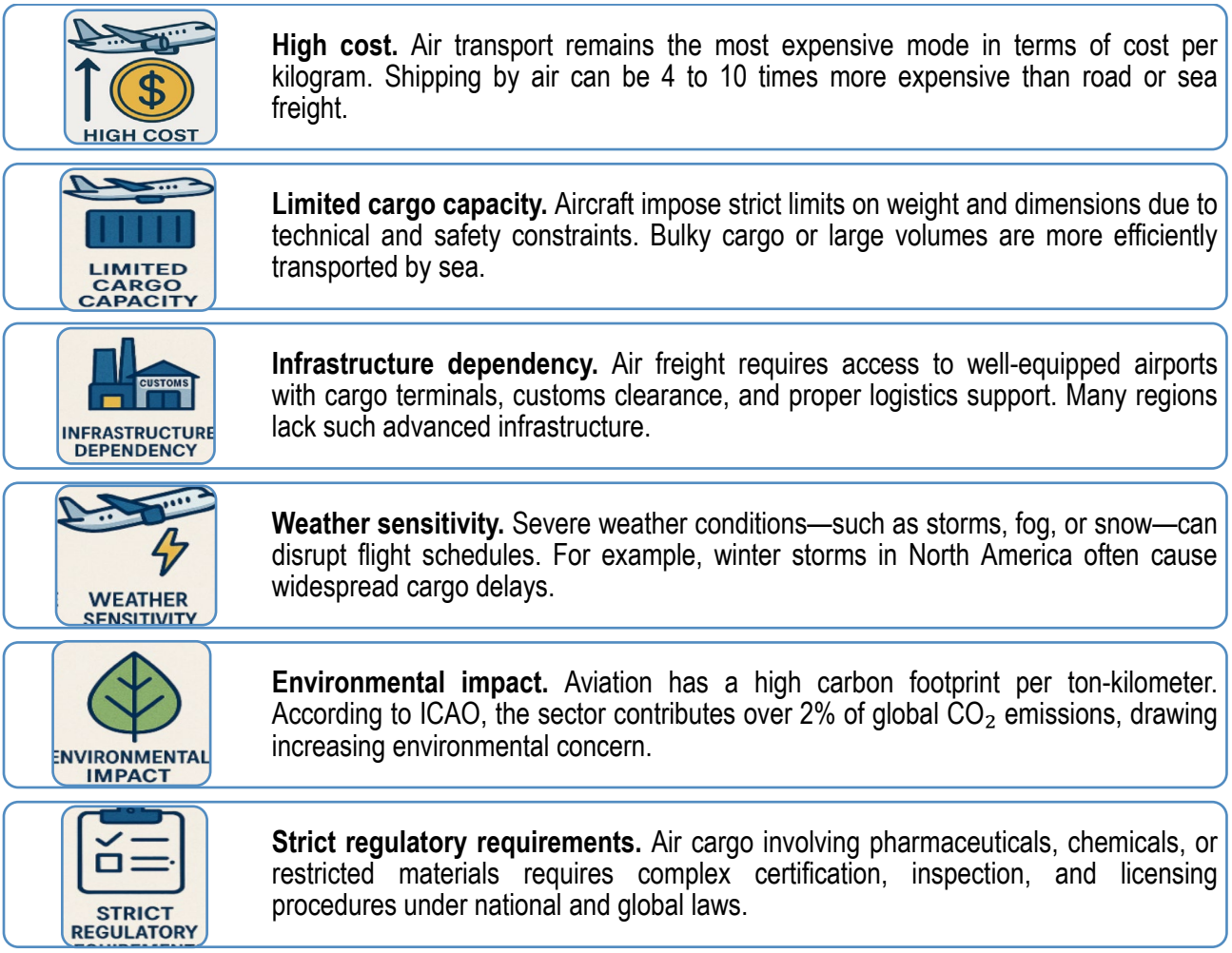

Figure 1. Limitations of air transport in integrated logistics systems
Source: compiled by the authors based on [3,4] [6]

A significant benefit of implementing digital technologies is the substantial reduction of logistics costs through the automation of core operational processes. Specialized IT solutions help optimize transportation routes, accelerate documentation procedures, minimize human errors, and ensure more efficient use of available resources. As a result, companies can enhance the productivity of their logistics units and strengthen their competitiveness within the global air transport environment [6].

Digitalization has become particularly relevant in conditions of global instability and rising risks linked to political, economic, or environmental factors. In such circumstances, the ability of logistics companies to respond quickly, adapt to changes, and maintain supply chain continuity is critically important. Digital tools that support analytics, forecasting, and automated decision-making serve as a foundation for the stable operation of logistics chains even under crisis conditions [7].

Another important aspect is the integrative function of digital technologies, which allows air transport to be combined with other transport modes into a unified multimodal system. Through digital platforms, logistics operators can manage the flow of goods, documentation, and information in a centralized manner across all stages of the supply chain – from dispatch to final delivery – thereby significantly increasing the efficiency of logistics operations.

Building a model for the efficiency of air transport requires consideration of numerous parameters: transport speed, delivery

reliability, costs, level of automation, ability to integrate with other modes of transport, and information interaction between all participants in the supply chain. Therefore, it is essential not only to conduct a technical and economic analysis but also to engage modern digital tools for modeling and tracking logistics operations.

One of the appropriate examples of a digital platform that can be applied to model the efficiency of air transport in integrated logistics systems is the AeroSync system. This platform is specifically designed to coordinate air cargo operations, automate data exchange between logistics stakeholders, and synchronize workflows with airports, customs authorities, warehouses, and ground carriers. AeroSync enables real-time tracking of cargo location, monitoring of handling times at logistics nodes, and calculation of key performance indicators (KPIs), including cost per shipment unit, idle time, and on-time delivery index [11].

Thus, AeroSync is a relevant platform for developing a model to evaluate the efficiency of air transport. It enables visualization and analysis of logistics processes, identification of bottlenecks, automation of reporting, and decision-making. Using AeroSync as the digital foundation of the model facilitates the integration of air transport into the overall logistics system of a company or logistics operator, ensuring transparency and manageability at all stages of the supply chain.

Figure 2 presents the AeroSync model diagram, which visually outlines the core structure and logic of an integrated logistics approach in the aviation sector. The model is divided into four key components: input factors, constraints, the integration process, and expected results. These elements are interconnected through directional flows, emphasizing how aviation-specific resources and external conditions are transformed into measurable economic, marketing, and social outcomes. The diagram also highlights the role of constraint management in optimizing system performance.

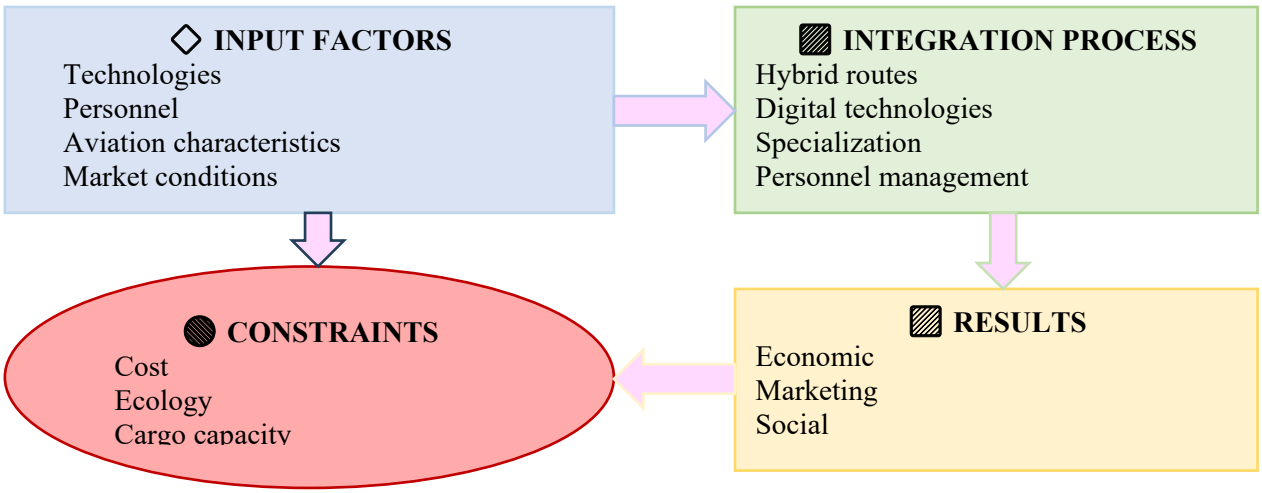

Figure 2. AeroSync model diagram
Source: compiled by the authors based on [11]

Figure 2 illustrates the AeroSync model diagram, which conceptually integrates key structural and functional components of an advanced logistics system tailored for the aviation sector. The model is logically divided into four interconnected blocks, each representing a specific stage or influence in the transformation of initial conditions into targeted outcomes. These blocks include input factors, constraints, the integration process, and final results. The entire system operates on the principle of dynamic

71-81
v.30 (2025)
https://smart-scm.org

interaction, where each component either initiates, regulates, or enhances the functioning of the next.

The first block – input factors – contains foundational elements such as technologies, personnel, aviation-specific characteristics, and prevailing market conditions. These factors serve as the core inputs that determine the capacity and potential of the logistics system. Their configuration influences the adaptability of the system to external changes and internal goals.

Beneath this block lies the Constraints component, which includes barriers such as cost, ecological impact, and cargo capacity limitations. These constraints may hinder system efficiency and operational feasibility. Importantly, the diagram suggests a feedback mechanism: through constraint management, these limitations can be addressed and minimized within the integration process, rather than treated as static obstacles.

The Integration Process block reflects the transformation stage, where input resources are aligned and optimized through hybrid routing strategies, digital technology adoption, process specialization, and effective personnel management. This is the operational core of the AeroSync model, aimed at achieving coordination and value creation across multiple aviation logistics activities.

The final block – results – captures the intended outcomes of the integrated system, grouped into economic, marketing, and social dimensions. These results reflect not only financial performance but also customer value and broader societal impact. The visual structure of the model emphasizes a forward-moving, value-generating logic, while also allowing for continuous adaptation through feedback from the constraints layer.

Overall, the AeroSync model highlights the importance of a balanced, system-wide approach where technological, organizational, and environmental considerations are all accounted for. The visual representation reinforces the idea that sustainable logistics solutions in aviation must be both strategically designed and operationally responsive.

Table 2 presents the advantages of using the AeroSync model to enhance the efficiency of air transport in integrated logistics systems. The listed benefits highlight the model's potential to improve coordination, adaptability, and performance through strategic integration, digital innovation, and effective constraint management.

Table 2 – Advantages of using the AeroSync Model to enhance the efficiency of air transport in integrated logistics systems

No.	Advantage	Description with Argumentative Examples
1.	Comprehensive integration	AeroSync provides a unified logical framework encompassing all key logistics components – from input factors to final outcomes. This alignment enables a structured connection between technologies, workforce, aviation-specific characteristics, and market conditions with actionable operational and strategic decisions.
2.	Proactive constraint management	The model incorporates not only the identification of critical barriers but also adaptive mechanisms to overcome them through the integration process. For instance, high air freight costs can be mitigated through precise route planning or multimodal transport strategies that optimize cost-effectiveness.
3.	Integration of digital technologies	AeroSync facilitates the implementation of tracking systems, RFID solutions, cloud-based logistics platforms, and analytical tools, enhancing transparency, speed, and real-time control. These technologies reduce cargo handling time, minimize losses, and optimize resource utilization.

4.	Multidimensional result orientation	The model emphasizes not only economic outcomes but also marketing and social impacts. This enables logistics operators to account for customer satisfaction, brand perception, service innovation, and corporate social responsibility–factors critical in today's competitive global environment.
5.	Support for strategic decision-making	With its logically interconnected components, AeroSync functions as an effective tool for scenario planning and strategic forecasting. It enables the simulation of network changes, assessment of infrastructure or regulatory shifts, and the formulation of long-term logistics policies.

Source: compiled by the authors based on [11]

The AeroSync model, which integrates key components of logistics systems, has been successfully implemented by several international logistics companies. Its application has contributed to the optimization of operational processes and a significant improvement in efficiency across multimodal transport environments.

SEKO Logistics adopted digital solutions that improved supply chain transparency and reduced transit times. Through the integration of innovative technologies, the company was able to enhance cargo handling efficiency and lower overall logistics costs, ensuring greater responsiveness to customer demands [12].

Omni Logistics applied hybrid routing strategies combined with advanced digital tools. This allowed the company to optimize the flow of goods, streamline scheduling, and improve shipment tracking, which resulted in reduced operational costs and better service quality [13].

Noatum Logistics implemented multimodal transport operations by integrating air, sea, and road freight. This approach shortened delivery times and enhanced the company's ability to adapt to variable market conditions, providing increased flexibility in logistics operations [14].

Logistics Plus leveraged the AeroSync model to strengthen warehouse management and improve supply chain coordination. As a result, the company ensured timely deliveries and maintained a high level of customer satisfaction by aligning logistics execution with strategic performance goals [15].

These cases demonstrate how the AeroSync model supports digital transformation, multimodal coordination, and strategic agility in the global logistics sector.

The AeroSync Efficiency model serves as a comprehensive analytical framework that systematizes the key factors influencing the performance of air transport within integrated logistics systems. It offers a structured approach to managing both internal resources and external challenges, enabling logistics enterprises to develop flexible and adaptive business models.

The model places particular emphasis on the role of innovative technologies, skilled personnel, hybrid routing strategies, and operational specialization. These elements collectively contribute to overcoming major constraints such as high operational costs, environmental impacts, limited cargo capacity, and infrastructure dependency. Through the integration of these components, the model facilitates the achievement of not only economic outcomes–such as cost reduction and optimized delivery times–but also marketing benefits, including improved service quality, enhanced customer loyalty, and strengthened corporate reputation.

AeroSync Efficiency is a universal and scalable tool applicable to a wide range of logistics companies engaged in multimodal transportation involving air freight. Its application enables the design of effective transport solutions that combine high speed, reliability, and operational flexibility. This is particularly relevant in the context of globalization, digital transformation, and intensified competition in the logistics

services market. Thus, the AeroSync model not only reflects the current logic of logistics management but also defines a strategic trajectory for its future development.

Conclusions. The efficiency of air transport in integrated logistics systems is determined by its ability to combine speed, reliability, and global reach within a complex multimodal framework. While air freight offers undeniable advantages–such as rapid transit times, secure handling of high-value cargo, and access to remote markets–it also faces notable limitations, including high operational costs and regulatory complexity. The integration of digital technologies and advanced management models like AeroSync enhances the potential of air transport by enabling real-time monitoring, constraint management, and strategic coordination across logistics chains. By aligning technological capabilities with operational needs, the AeroSync model contributes to the development of responsive, resilient, and customer-focused logistics systems, reinforcing the role of air transport as a vital component in modern global supply networks.

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SMART CONTRACT AS A MECHANISM FOR MANAGING THE LOGISTICS ACTIVITIES OF TRANSPORT COMPANIES: INTERNATIONAL PRACTICE

Harmash Oleh, Trushkina Nataliia, Yevtushenko Kyryl, Shkrygun Yuliya. «SMART contract as a mechanism for managing the logistics activities of transport companies: international practice». *Currently, smart contracts are recognized as an effective mechanism for managing logistics activities and an innovative technology for managing relationships between a company and consumers based on blockchain. This technology is widely used in various sectors of the economy, including logistics and transport. Many transport companies in different countries of the world are turning to the use of smart contracts in their logistics*

82-101
v.30 (2025)
https://smart-scm.org

activities. This is due to the fact that smart contracts simplify the management and processing of documents, contribute to improving the quality and level of service to customers and various groups of stakeholders, transforming the customer relationship management system, and also provide reliable data protection and help transport companies save time on routine operations, which ultimately reduces operating costs.

In view of the above, the purpose of the article is to substantiate the need to use smart contacts as a tool to improve the efficiency of logistics management of transport companies in the era of digitalization.

As part of the study, a bibliometric analysis of the database of scientific publications was conducted to identify the most cited works and authors. The results of the study will provide a holistic view of the current state and prospects for the development of research on reengineering logistics processes in the activities of transport companies when implementing smart contract technology.

The article studies and summarizes scientific approaches to defining the essence and content of the concept of "smart contract". The features of the use of smart contract technology in the USA, the European Union and Singapore are studied. The main indicators of the development of the smart contract system in the world are analyzed.

The sequence of development of the smart contract system in the transport services sector is determined. A matrix of interests and goals of participants in the transport services market, which are provided using smart contract technology, is proposed. C The factors and conditions for the successful implementation of smart contract technology in the logistics activities of a transport company are determined. Alternative scenarios for the transition to smart contract technology as a mechanism for managing the logistics activities of transport companies are proposed.

***Keywords**:* transport sector, transport company, transport network, transport services, logistics management, logistics activities, digital transformation, digitalization, digital logistics, digital technologies, information and communication systems, blockchain, smart contract, contractual relationships, procurement management, customer relationship management, strategic management, bibliometric analysis

Олег Гармаш, Наталія Трушкіна, Кирил Євтушенко, Юлія Шкригун. «Смарт-контракт як механізм управління логістичною діяльністю транспортних компаній: міжнародна практика». *На сьогодні смарт-контракти визнаються ефективним механізмом управління логістичною діяльністю та інноваційною технологією налагодження взаємодії між компанією та споживачами на основі блокчейну. Ця технологія широко застосовується в різних секторах економіки, зокрема в логістиці та транспорті. Багато транспортних компаній у різних країнах світу впроваджують смарт-контракти у свою логістичну діяльність. Це пов'язано з тим, що смарт-контракти спрощують управління та обробку документації, сприяють підвищенню якості та рівня обслуговування клієнтів і зацікавлених сторін, трансформують систему управління взаємовідносинами з клієнтами, забезпечують надійний захист даних і дозволяють транспортним компаніям економити час на рутинних операціях, що в кінцевому підсумку знижує операційні витрати.*

У зв'язку з вищезазначеним, метою статті є обґрунтування необхідності використання смарт-контрактів як інструменту підвищення ефективності управління логістикою транспортних компаній в умовах цифровізації.

У межах дослідження проведено бібліометричний аналіз бази наукових публікацій з метою виявлення найбільш цитованих робіт та авторів. Результати дослідження дозволять сформувати цілісне уявлення про сучасний стан і перспективи розвитку наукових досліджень у сфері реінжинірингу логістичних процесів у діяльності транспортних компаній за умови впровадження технології смарт-контрактів.

82-101
v.30 (2025)
https://smart-scm.org

У статті досліджено та узагальнено наукові підходи до визначення сутності та змісту поняття «смарт-контракт». Вивчено особливості використання технології смарт-контрактів у США, Європейському Союзі та Сінгапурі. Проаналізовано основні показники розвитку системи смарт-контрактів у світі.

Визначено послідовність розвитку системи смарт-контрактів у секторі транспортних послуг. Запропоновано матрицю інтересів і цілей учасників ринку транспортних послуг, які забезпечуються за допомогою технології смарт-контрактів. Визначено фактори та умови успішного впровадження технології смарт-контрактів у логістичну діяльність транспортної компанії. Запропоновано альтернативні сценарії переходу до технології смарт-контрактів як механізму управління логістикою транспортних компаній.

Ключові слова: транспортний сектор, транспортна компанія, транспортна мережа, транспортні послуги, управління логістикою, логістична діяльність, цифрова трансформація, цифровізація, цифрова логістика, цифрові технології, інформаційно-комунікаційні системи, блокчейн, смарт-контракт, договірні відносини, управління закупівлями, управління взаємовідносинами з клієнтами, стратегічне управління, бібліометричний аналіз.

Intraduction. At the current stage, digitalization processes [1-2] cover all areas of economic activity, including the sphere of transport and logistics services [3-4]. At the same time, strategic management of contractual relations in the field of transport services is a pressing task. But it should be noted that contractual relations in the context of digitalization are undergoing quite serious changes, the complexity of which is largely due to the lack of legal regulation of the digital economy as a whole. And it is the aspects of value formation (organization, processes, personnel, performance management, cooperation) identified by analysts of the Boston Consulting Group that can be fully applied as factors in changing digital contractual relations.

One of the qualitatively new digital technologies today is blockchain and the smart contract created on its basis. According to Statista [5], global spending on blockchain solutions increased 2.9 times from 2021 to 2024, from 6.6 to 19 billion dollars. In 2021, 45% of respondents said that their companies were working on secure information exchange as a use case for blockchain technology. This makes blockchain the most popular use case for the technology [6].

According to Statista's first forecast (2022) [7], blockchain technology will be worth 1,235 billion dollars by 2030, with an average annual growth rate of 82.8%. According to the second forecast (2023) [7], the value of blockchain technology will be 943 billion dollars in 2032, with a CAGR of 56.1%.

The involvement of smart contracts in the regulation of contractual relations in the field of transport services is a popular innovation in practice-oriented contracting, algorithmically developing and complementing the theoretical and methodological principles of managing logistics systems developed and successfully applied in transport companies [8]. The focus on proven solutions is due to the increased level of maturity of existing logistics technologies, the adaptation of which to digital Industry 5.0 [1] and smart contracts can be carried out with minimal financial costs and market risks. From the standpoint of management theory, smart contracts formalize the boundaries of logistics business processes and ensure that factories fulfill identifiable conditions of a digital contract attached to the full life cycle of a product or to its individual stages in each facility of the transport infrastructure, elements of the transport and warehouse network.

In view of this, the issues of applying smart contract technology in the logistics activities of transport and logistics companies in the new digital era are becoming more relevant.

Literature and researches review. Analysis of the scientific literature shows that

scientists pay significant attention to the study of new forms of digital transformation of various logistics systems, the development of digital models and strategies for their development in the era of Industry 4.0 and 5.0.

Various aspects of the application of blockchain technologies and tools in the logistics management system and supply chain management are among the scientific interests of many leading foreign scientists (P. Centobelli et al. [9]; S. E. Chang & Y. Chen [10]; A. Dorri et al. [11]; T. M. Fernández-Caramés et al. [12]; A. Gurtu & J. Johny [13]; D. Minoli & B. Occhiogrosso [14]; J. Moosavi et al. [15]).

As the analysis shows, in recent decades, publications by foreign (C. Buchleitner & T. Rabl [16]; M. Durovic & A. Janssen [17]; B. Hu et al. [18]; A. Janssen [19]; M. Kaulartz & J. Heckmann [20]; S. Lin et al. [21]; E. Negara et al. [22]; N. Quan et al. [23]; A. Rab [24]; A. Stazi [25]; N. Szabo [26]; S. Tern [27]; Z. Wei et al. [28]; G. Wu et al. [29]) and Ukrainian researchers (A. Ivanov & V. Shmyha [30]; S. Klimovych [31]; Y. Kryvenko [32]; L. Mamchur & O. Nedybalyuk [33]; Y. Manuilov [34]; K. Nekit [35]; V. Priamitsyn & K. Kovalyk [36]) have appeared that address the issue of using smart contracts in various areas of the economy.

According to A. Ivanov & V. Shmyha [30], the study of problematic aspects of the use of smart contracts in contractual legal relations remains relevant today. One of the most important problems associated with the use of smart contracts is the problem of protecting the rights of its participants. In addition, according to scientists [30], the issue of making payments under smart contracts is debatable today.

Smart contracts were first put into practice with the advent of blockchain technologies. The author of the idea of a smart contract is an American scientist, cryptography specialist Nick Szabo [26]. In 1996, he gave the following definition of a smart contract: "A set of obligations recorded in digital form, including protocols by which the parties fulfil these obligations" [26]. That is, a smart contract is a computer protocol that independently conducts transactions and controls their execution using mathematical algorithms.

It is worth noting that in recent years many scientific works R. Ahmad et al. [37]; M. Alqarni et al. [38]; N. Angstein & J. Parung [39]; B. Arun Kumar [40]; R. Casado-Vara [41]; H. Hasan et al. [42]; D. Hensher [43]; S. Liu et al. [44]; Y. Mezquita et al. [45]; V. Varriale et al. [46]) have been published, in which the introduction of smart contract technology, which has significant potential for solving the presented problems, is considered as one of the most promising areas of digitalization of logistics processes in transport companies.

Scientists N. Angstein & J. Parung [39] recommended the use of smart contracts that allow consumers to easily identify and order logistics services according to their needs. Authors R. Casado-Vara et al. [41] developed a system that uses smart contracts to remove intermediaries and accelerate logistics activities. In addition, a multi-agent system is used to coordinate all logistics services, smart contracts and enforce their terms. The new model should combine smart contracts and a multi-agent system to improve the current logistics system by increasing organization, security and significantly reducing distribution time.

In [42], scientists emphasize that effective tracking of shipments is crucial for managing global trade and logistics activities. The volume of global container movement, combined with information opacity and process complexity, requires the implementation of a reliable technological solution with real-time tracking capabilities. Blockchain is a new technology that offers the necessary platform for tracking and managing the movement of shipments in the supply chain using a peer-to-peer, secure, distributed registry and without intermediaries or trusted third parties [42].

Based on bibliometric analysis, it is proven that certain issues of implementing smart contracts in the logistics activities of transport companies are among the long-

term scientific interests of prominent foreign scientists. According to the title of articles, abstracts and keywords "Smart contract" and "Transport or Logistics or Transport Company" in the international scientometric database Scopus, 729 documents were found for 1989-2025. These issues have become particularly relevant in the period from 2017. During 2017-2024, the number of scientific papers increased from 8 to 144 or 18 times. During this period, the average growth rate of the number of papers on the selected topic was 51.1%.

Key publications that publish works on improving the efficiency of logistics management using smart contracts include: IEEE Access (27 documents), Lecture Notes In Networks And Systems (24), ACM International Conference Proceeding Series (20), Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics (19), Communications In Computer And Information Science (14), Sustainability Switzerland (14), Lecture Notes In Electrical Engineering (10 documents).

The results of the analysis show that most of the works on the outlined problem are published by scientists from India (174 documents), China (115), United States (53), United Kingdom (29), Germany (28), Australia (26), Saudi Arabia (25), France (24), Taiwan (24), Italy (21), Spain (20 documents). In Ukraine, only 3 documents were found using the specified search criteria.

By document type, works can be ranked as follows: 1st place is occupied by the works of an approbatory nature (43.3% of the total number of publications); 2nd – scientific articles (36.2%); 3rd – conference review materials (8.1%); 4th – chapters of books or monographs (7.5%); 5th – review articles (3.2%); 6th place – books (0.8%).

The term "Smart contract" is interdisciplinary in nature, used in research in various fields of science, namely: it is found in publications in computer science (31.1% of the total number of works); engineering (21.3%); mathematics (8.6%); decision science (8.3%); business, management, economics (5.4%); social sciences (4.4%), etc.

The main sponsors that finance scientific publications on selected topics include the following: National Natural Science Foundation of China (33 documents), European Commission (26), Ministry of Science and Technology of the People's Republic of China (24), National Key Research and Development Program of China (15), Horizon 2020 Framework Programme (12), European Regional Development Fund (9), Ministry of Education of the People's Republic of China (9), National Research Foundation of Korea (7 documents). Thus, the analysis of publication activity confirmed that since 2017 there has been an increase in scientific interest in studying the application of smart contracts in the logistics management system of transport companies in the context of global digital transformations.

It should be noted that the visualization of the network map of 252 keywords based on bibliographic data allowed us to identify 8 clusters (Fig. 1), which characterize the main areas of research: blockchain, network security, Internet of Things (IoT), machine learning, cybersecurity, supply chain, supply chain management, smart contract, logistics, information systems, blockchain technology, sustainable development, Artificial Intellidence, transformation system, smart city, intelligent systems.

Despite the wide range of scientific research on the chosen topic, the multifaceted nature and debatability of individual issues require further development. And especially the solution of this problem is relevant at the current stage of changing strategic thinking and the paradigm of logistics management of transport companies in the context of Industry 5.0.

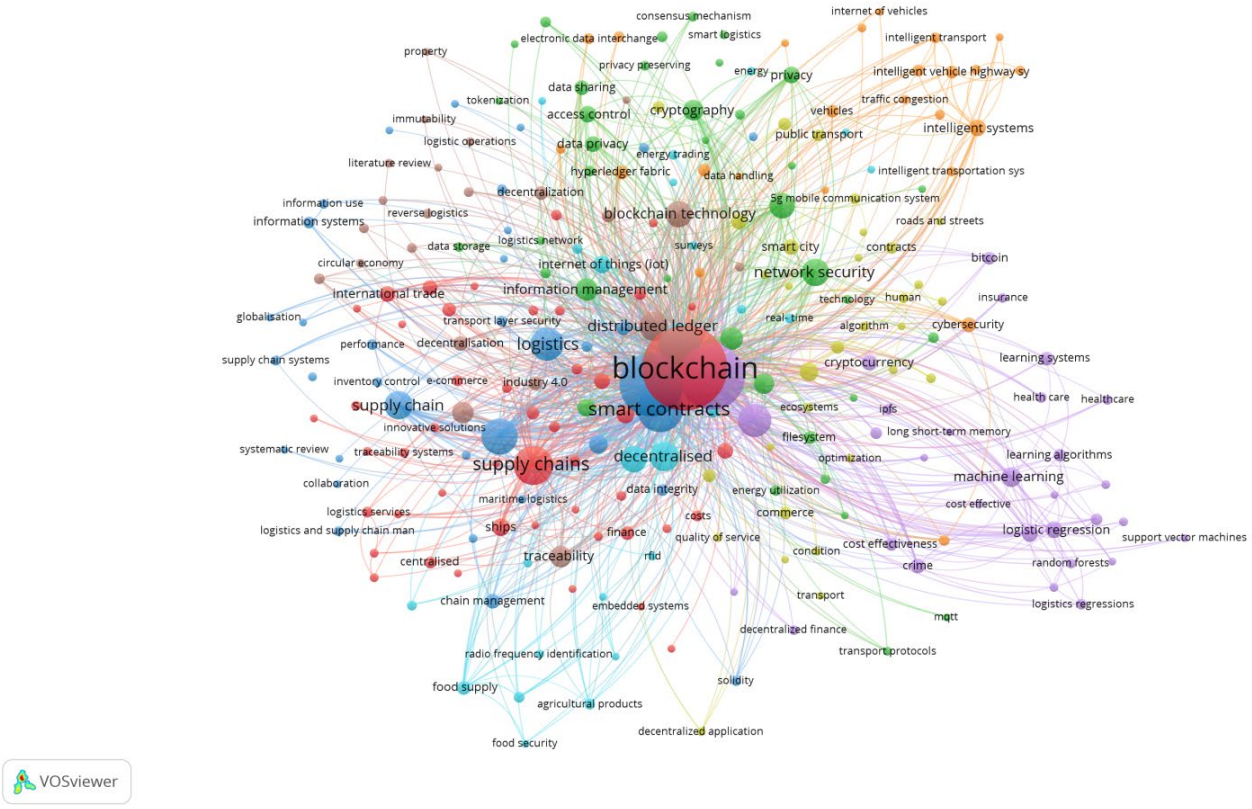

Figure 1. Network visualization of citations of articles on the use of smart contracts in the logistics activities of transport companies

Source: built by the authors based on data from the Scopus scientometric database using the VOSviewer tool.

Aim and objectives. The outlined problem determined the purpose of this article, which is to substantiate the need to use smart contacts as a tool for increasing the efficiency of logistics management of transport companies in the era of digitalization.

The theoretical and methodological basis of the study is the provisions of institutional theory, digital economics, concepts of strategic and logistics management, enterprise development management, customer relationship management, supply chain management. The following general scientific methods were used in the research process: analysis and synthesis, expert survey, SWOT analysis, bibliometric analysis, comparison and classification, structural and logical generalization, as well as the Ishikawa diagram.

Results, analysis and discussion. According to Grand View Research [47], the global smart contract market was valued at 684.3 million dollars in 2022. This figure is expected to grow at a compound annual growth rate of 82.2% between 2023 and 2030. The growth is primarily driven by the increasing adoption of blockchain technology, technological innovation, efficiency gains, cost savings, and the growing demand for decentralized finance (DeFi). Smart contracts are based on blockchain technology, which is becoming increasingly popular as businesses seek more secure, efficient, and transparent ways to manage data and execute transactions. In addition, smart contracts are a critical component of the DeFi ecosystem, which has been rapidly developing in recent years. According to Fortune Business Insights [48], the global smart contract market was valued at 2.14 billion dollars in 2024. It is projected to be worth 2.69 billion dollars in 2025 and reach

12.07 billion dollars by 2032, exhibiting a CAGR of 23.9% during the forecast period.

The growth of the smart contracts market can be observed due to several factors, such as the increasing adoption of blockchain technology across various industries and supply chains, and the use of online banking. In addition, the emergence of DApps (decentralized applications) is a significant driver increasing the global market share. According to a report published by DappRadar in 2022, the number of DApp users increased by 396% daily during 2024, reaching 2.4 million users [48].

In 2024, North America dominated the global smart contracts market with a share of 35.1%. The region's leadership can be attributed to a strong technology ecosystem and a highly skilled workforce. In addition, several smart contract startups have emerged in the region as a result of early adoption of blockchain technology and a supportive ecosystem for startups. These factors have enabled North American firms to lead the market and contribute to regional dominance [48].

As evidenced by an analysis of regulatory documents and information materials, the lack of a unified international legal framework for the operation of smart contracts gives rise to various approaches to defining the concept of a smart contract. Let's consider the example of the United States, the European Union and Singapore.

According to Arizona Law, a smart contract is an event-driven computer program that operates in a distributed, decentralized registry that can manage the transfer of assets and ensure a record of it in the registry.

A smart contract is an agreement whose execution is automated. This automatic execution is carried out using a computer running code converted from legal text into an executable program. A smart contract is a set of computer codes between two or more parties that, within the framework of blockchain technology, represent a series of rules agreed upon by the parties. It should be noted that a smart contract is not an agreement from a legal point of view, since it does not fully or partially meet the requirements of US law.

To date, in the United States, a smart contract does not have such flexibility as cancellation or change of conditions. Amending a smart contract may result in higher costs than changing a text contract. There are projects underway to create smart contracts that can be terminated at any time and more easily amended.

In European law, a smart contract is not an agreement. It is a program code, or more precisely, a very specific description that determines the order of actions in blockchain technology. A smart contract is a database where various events are predetermined.

According to M. Kaulartz and J. Heckmann [20], the program code in a smart contract does not serve to express the will. A smart contract cannot be identified with a written document that reflects the content of the will of the parties. It only fulfils the terms of the contract.

According to M. Kaulartz and J. Heckmann [20], the parties to the contract can agree that their relations will be governed by a smart contract that performs the functions of a written contract. In this case, the program code will be used to express the will. In addition, the authors believe that the possibility of an arbitrator's intervention should be provided.

An arbitrator can be any disinterested third party who would decide on the presence of a software error that contradicts the contract. Such an arbitrator can be given the opportunity to monitor the execution of the contract. A smart contract can only be executed as written in the code, so the arbitrator's intervention should also be programmed in advance.

C. Buchleitner and T. Rabl [16] point out that the impossibility of a return executed via blockchain is only a technical impossibility. This does not cancel the fact that the parties must retain the right to withdraw from the contract or the right to challenge. Difficulties

for the parties to a smart contract: when one party declares that the obligations under the contract must be changed under circumstances that they have not previously considered. In this regard, it is necessary to provide the smart contract with a "fail-safe" code that would allow the smart contract to be terminated in certain agreed scenarios by either party to the contract. In Singapore, a smart contract is a blockchain-based software code that runs during transactions. A smart contract is a computer protocol that ensures the execution of contractual provisions based on certain events.

Since it is virtually impossible to rewrite information after blocks are hashed, the contracting parties can only make changes to a smart contract by drafting another smart contract. The two parties can also restore the terms of the contract in natural language using the smart contract software code. And in the event of disagreement by either party regarding any term or provision of a smart contract relative to a term or provision enshrined in the text of a traditional contract, lead to a dispute about the method of actual implementation of the obligation in the smart contract.

Based on the analysis of scientific literature, it has been established that smart contracts in economic relations of entities act as elements of a management system that automatically control production, service, financial and information flows of movement of material and intangible assets arising in the operating activities of enterprises or digital factories and corresponding to their business interests.

A smart contract is a program (script) aimed at automating business processes. It is executed automatically on a virtual machine and is a sequential algorithm for monitoring the occurrence of a chain of events for the execution of each subsequent event based on an objective record of the fact of the occurrence of the previous one. To ensure the objectivity and transparency of the chain of events, all actions are recorded in a distributed registry (blockchain).

A smart contract is an innovative technology that allows you to optimize various processes and methods of interaction between computers and people. It first appeared in the depths of the cryptocurrency industry and became the basis for launching many decentralized systems of various types. Also, thanks to the spread of this technology, many existing projects have received new opportunities for development.

According to G. Prause [49], a smart contract as an electronic transaction protocol designed to digitally verify or enforce the terms of a basic legal contract. In other words, the fulfilment of general contractual requirements, including payments, legal obligations, and enforcement without the participation of third parties.

A. Thakre et al. [50] developed a model that potentially allows for stakeholders to be held liable for breach of contract terms or rewarded for successfully fulfilling the terms pre-configured in the contract algorithm.

A. Ivanov & V. Shmyha [30], based on a study of doctrinal approaches to understanding the concept of "smart contract", concluded that this category covers both technical and legal aspects. Having clarified the essence and content of the concept of "smart contract", it was determined that the key goal of a smart contract is to reduce or completely eliminate the human (subjective) factor in the process of conducting a business transaction, thereby minimizing the risks of fraud and errors [30]. As defined by S. Klimovych [31], smart contracts are one of the most innovative and promising technologies that have emerged as a result of the development of the blockchain. In essence, a smart contract is a computer algorithm designed to conclude and support self-executing contracts that are implemented in a blockchain environment. The main idea of smart contracts is to ensure automatic execution of agreements between parties without the need to involve intermediaries such as banks, lawyers or brokers.

The scientist Y. Kryvenko [32] interprets a smart contract as an algorithm designed to automate the process of contract execution. It is a set of rules and a sequence of actions for their execution. These rules are first stored as contract conditions, then they are automatically checked, and then the conditions are executed according to the digital protocol.

According to the author [32], depending on the amount of data entered, smart contracts are classified as: fully automated, i.e. all conditions are written in the program; partially automated, i.e. one part of the conditions is written in the program, the other – on paper. In addition, smart contracts are classified according to the scope of application: contracts in the field of property relations control; financial services – trading on the exchange, participation in auctions; fulfilment of obligations under various forms of banking credit products at the time of the occurrence of events; social services, including conducting various votes, elections, insurance processes; organization of management of delivery and storage of products.

Thus, a smart contract is the performance of obligations, as well as the implementation, modification and termination of rights under an obligation, which occurs automatically on the basis of an electronic algorithm agreed upon by the parties through their previously expressed consent to the terms of the contract.

A smart contract is a standard (special) contractual structure – an agreement concluded using electronic or other technical means. Moreover, it should be clearly indicated that a smart contract cannot be qualified as an independent way to ensure the fulfillment of obligations.

Smart contracts based on the blockchain system are defined as a digital agreement (a system for digitally recording contractual obligations), which:

- is recorded on a digital medium using software;
- is stored using blockchain technology in a decentralized manner, which makes it possible to clearly save the original data without the possibility of changing it by one of the parties;
- is a certain set of digital operations that are performed automatically without outside interference;
- minimizes material, technical and time costs;
- reduces the likelihood of risky situations.

It can be argued that a smart contract is not an independent type of contractual interaction, but acts as an effective way of formalizing an agreement between the parties, which is based on the blockchain system and minimizes material, technical and time costs as much as possible, reduces the likelihood of a risky situation in the legal field. The approval of this definition at the legislative level will solve the following problems:

- establishes the legitimacy of such contractual interaction at the legislative level;
- ensures the protection of contractual relations at the legislative level;
- smart contracts can act as legitimate electronic evidence.

A smart contract is an agreement with automatic execution. Such a contract can be called a logical continuation of the classical information exchange system. As a rule, automated execution is based on a clear program code, which is responsible for translating legal language into automated software execution, which has the legitimate right to determine the activities of digital or physical objects. Smart contracts mean a certain set of software functionality that is executed in an automated mode based on the initial conditions. The main advantages of the technology include:

- security – the operating principle is based on blockchain technology;
- transparency and openness of all stages and events (transactions) of transportation;

• autonomy and, as a result, acceleration of document flow processes, financial settlements;

• continuity of the information cycle, which provides fast and guaranteed access to the necessary information, and also allows you to immediately respond to changes in processes.

But the smart contract has a number of disadvantages. Since the smart contract system is based on blockchain, the problems that exist today in this technology are partially common to such contracts. They can be conditionally divided into three groups: technological, legal, organizational.

1) Technological problems are related to the possibility of scaling (cross-platforms already partially solve this problem). Since smart contracts are self-executing codes that cannot be changed after loading, errors can lead to serious losses. In most cases, they are due to the human factor in the design, development and testing of a smart contract.

2) Legal difficulties are explained by the lack of legal acts. Thus, there is no unified approach to understanding the process of integrating smart contracts into the current system of legal relations. On the one hand, experts argue that the smart contract system does not require a special legislative framework for widespread use. The existing system of contractual interaction meets all the basic postulates necessary for the implementation of the smart contract system. However, it should be noted that on March 14, 2023, the European Parliament voted to adopt a new law on the regulation of smart contracts. We are talking about the implementation of an "emergency switch for resetting activity" – the so-called Kill Switch function.

A smart contract is an agreement recorded in the form of computer code and cryptographically signed by the parties to the transaction. All provisions of such an agreement must be available on a trusted platform, for example, on a cryptocurrency one. After signing by the parties, the smart contract is saved in the blockchain and comes into force.

The provisions included in the law mean that smart contracts must have access to control and protect trade secrets. They must also have functions for suspension or reset. But experts fear that such capabilities may contradict the very concept of smart contracts. The fact is that the document does not specify who exactly can initiate the shutdown or reset of a smart contract. In other words, such an approach contradicts the fundamental principle according to which automated programs cannot be changed by anyone. Another group of experts talks about the need for regulatory control of the mechanism of smart contracts. From their position, after smart contracts are legalized, it will be possible to conclude contracts, the fulfilment of the terms of which will be monitored by computer programs. Such a condition can be, for example, a payment schedule – payments will be made automatically.

3) Organizational problems are primarily associated with the unwillingness of businesses to work within the framework of smart contracts. The reason is the lack of flexibility of such contracts: it is impossible to revoke, cancel or appeal the transaction. In other words, unlike traditional contracts, the parties do not have the opportunity to agree or adjust the terms of the transaction already in the process of transportation.

Creating a smart contract requires care and understanding of the specifics of how blockchain platforms work. Following the steps described below, you can successfully create a smart contract and implement it in the blockchain ecosystem.

Selecting a blockchain platform: The first step is to choose a blockchain platform on which you want to deploy your smart contract. Ethereum, Binance Smart Chain, and other platforms provide various features and tools for creating smart contracts.

Defining the purpose of the contract: Next, you need to determine the purpose of the smart contract. This can be the

automation of financial transactions, the creation of digital assets, or the management of voting processes.

Defining the programming language: It is important to clearly define the programming language used on the chosen blockchain platform. For example, Solidity is a popular language for smart contracts on Ethereum. Choosing a development environment: An important step is to set up a development environment that supports the blockchain programming language. Examples of such environments are Remix and Visual Studio Code with an extension for Solidity.

Writing the smart contract code: After all the settings are done, the coding stage begins. Here, it is important to consider the security of the smart contract, since ready-made solutions placed on the blockchain cannot be changed.

Testing: It is extremely important to test your smart contract in various scenarios. Here, you can use blockchain test networks to avoid potential problems in a real environment.

Deployment on the blockchain: The penultimate step will be to deploy the smart contract on the chosen platform. You should pay attention to the fees, which may vary depending on the chosen platform.

Monitoring and maintenance: It is necessary to monitor the operation of the smart contract and promptly respond to any problems. If necessary or if errors are detected, you can release an updated version of the contract.

Now let's consider the implementation of smart contract technology in the organization of logistics processes of a transport company. Smart contracts are software that operates on the basis of blockchain technology. The tool allows you to conclude and fulfil contracts without the involvement of intermediaries and additional checks. In logistics, smart contracts can be used to automate the processes of cargo transportation, document flow and mutual settlements.

In logistics, smart contracts can be used:

• to conduct auctions among suppliers of goods and services to ensure an independent determination of the winner and record the results of the auction;

• to organize electronic document flow of shipping documents (an alternative to using digital signature technology to record each stage of the transportation process in the blockchain);

• control of information exchange with Internet of Things (IoT) objects and response by sending a signal at the moment of violation of the parameters of the IoT object set in smart contracts;

• settlements between the customer and the contractor of the transportation upon the fact of execution of the transportation in strict accordance with the terms of payment under the transportation contract;

• automation of information exchange and subsequent movement of stocks within the framework of solutions for inventory management in supply chains.

The value of a smart contract using blockchain technology is that it ensures strict adherence to a given business process scheme, as well as the autonomy of the smart contract algorithm and the transparency of operations – and, as a result, the ability to confirm the authenticity of events, the reliability of data storage in a distributed registry.

Based on the specifics of their application, smart contracts allow you to build complex business processes (participants in which may have multidirectional goals), ensure the security and sustainability of supply chains. They can also ensure the transparency of operations in the supply chain – without the possibility of making unauthorized adjustments to the data and informing participants in logistics processes about the movement of goods and documents in supply chains.

Thus, the scope of application of smart contracts in the logistics management system of enterprises in the field of transport services is quite extensive, namely:

• multimodal and cross-border transportation;

• organization of document flow, which is especially important for sea and rail transportation (in which the status of customs documents is obtained and transport papers are viewed);

• delivery of cargo at the specified time, which is important for courier companies;

• receiving cargo tracking, which is necessary for complex multimodal transportation, where many participants are involved.

Smart contracts allow the use of complex business operations with a large number of participants with different roles in the process, and also ensure the autonomy of the algorithm execution and transparency of actions at all stages of transportation, guaranteeing the reliability and immutability of events.

At the same time, there are problems and limitations on the use of smart contracts in the logistics management of service enterprises. All existing limitations for the development of smart contracts in logistics can be divided into two parts. Firstly, these are limitations in the development of blockchain technology, which is necessary for the functioning of smart contracts. And secondly, limitations associated with legislative regulation, with the maturity and readiness of society and business to implement smart contracts.

Blockchain technology is already used quite widely both in logistics and in other areas of business and public administration. A smart contract is unthinkable without a blockchain, since the smart contract algorithm transmits information about events to the blockchain that require verification/saving in a block. However, due to the fee for registering transactions in the blockchain and the use of some cryptocurrency for payment, there are difficulties with cross-platform compatibility. This means that a solution using a specific blockchain technology platform is not always compatible with other solutions. Which necessitates linking to some of the most common platforms – for example, Ethereum, to use its cryptocurrency. To solve this problem, cross-platform solutions are being developed: for example, Polkadot, Cosmos, Thepower, where you can create separate blockchains (they are also called parachains) that interact with each other and with external networks - such as Bitcoin, Ethereum.

In addition, there are all the elements of institutional and socio-economic barriers to the development of blockchain technology and related applications.

Society in general and business in particular are also not ready to implement smart contracts due to the established opacity of relationships between participants. Large companies are not ready to refuse to finance their own working capital at the expense of suppliers, not only setting long payment deferrals, but also violating these deadlines. Banks are not ready to provide automated access for the fulfillment of obligations by their clients by automatically writing off funds in favor of the counterparty within the framework of a smart contract.

An additional important factor is the digital immaturity of business, which consists in the fact that many business processes are not only not automated, but not even formalized.

The search for solutions to the above problems will allow the development of blockchain technologies in logistics activities. Blockchain technologies can already be and are partially used in logistics. Examples include private solutions for traceability in supply chains and international maritime transport. In the short term, the transport industry is already ready to offer the use of blockchain in the following areas:

• bidding of resource suppliers (commodity auctions, freight rate auctions for transportation);

• transfer of delivery stage data; implementation of smart contracts to automate settlements between supply chain participants;

• control and management of IoT objects: sensors, electronic seals, tracking systems;

• control and management of electronic document flow of transportation documents.

In the longer term, the use of blockchain technology is likely for such areas and tasks as monitoring unmanned transport to ensure the safety of operation and ensuring end-to-end electronic document flow between different modes of transport and different participants (companies, government and international structures).

In addition, this is the control and management of the transportation of goods and passengers by different modes of transport (both unmanned and manned vehicles), as well as warehousing and distribution based on seamless automated systems for interaction of networks and objects of the transport and logistics infrastructure. It should be noted that the popularity of smart contracts is growing every year – this tool is being implemented all over the world to solve logistics problems. For example, in 2018, IBM and Maersk developed a container management solution that transmits temperature, pressure and vibration data in real time and records it all in a secure and transparent blockchain in accordance with the terms of the smart contract. Information about any fluctuations is transmitted to counterparties. DB Schenker is a German company specializing in logistics services that use smart contracts to more accurately track cargo and manage warehouse stocks. The well-known Walmart chain has implemented a system for tracking supply chains using smart contracts.

However, the increasing implementation of smart contracts in the business processes of companies will force the latter to face new cyber threats. An example is the 2016 attack on the DAO, a decentralized autonomous organization, which is a crowdfunding platform on the Ethereum blockchain. The attackers were able to steal cryptocurrency worth more than $ 60 million by taking advantage of a flaw in the smart contract. According to Hosho, in 2018, security vulnerabilities cost blockchain companies more than 2 billion dollars. As the audit showed, at least 1 in 4 smart contracts had critical vulnerabilities, and 3 out of 5 had one security issue. A service such as smart contract audit helps to solve the problem. Today, a new class of startups has already emerged that implement technologies to protect corporate blockchain systems with an emphasis on smart contract audit. Thus, they use artificial intelligence technology to monitor transactions, which allows them to identify suspicious activity, as well as scan the code itself for known vulnerabilities. However, auditing smart contracts is still expensive and time-consuming.

Thus, with the help of smart contracts, logistics companies can establish a chain of cargo movement (tracking), which allows tracking the movement from the point of departure to the destination, including and detailing all intermediate stages (shoulders) of cargo transportation events. This increases the level of security and reduces the number of "gray" zones (areas where there is no information on the movement of cargo) and lost shipments.

Smart contracts can define delivery conditions, including terms, routes, volume, cargo characteristics and cost of services. They can also automatically determine the price of transportation based on transport tariffs, both their own and service providers, without the participation of intermediaries: banks, insurance companies and agents, which makes the contracting process more efficient. Smart contracts are also capable of automating payment and financial accounting processes, allowing for automatic calculation of amounts and payment of services of suppliers and carriers without intermediaries. This speeds up the process of sending and receiving payments. The sequence of development of the smart contract system in the transport sector can be presented in 3 levels (Table 1).

A necessary condition for maintaining the sustainability of the transport infrastructure and realizing the potential for its further development is the focus on developing mechanisms that ensure the interrelation of interests and goals of individual participants in the transport services market. The analysis

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of their strategic goals and economic performance indicators, conflict areas during interaction during the implementation of the transport and logistics process made it possible to specify the interests that can be potentially achieved by smart contract technology (Table 2).

Table 1. Sequence of development of the smart contract system in the transport services sector

Levels	Participants in the transport services market
Level I	Clients
Level II	Transport companies ↔ warehouse service operators ↔ customs and its regional branches
Level III	Logistics operators (3PL, 4PL, 5PL) ↔ freight forwarding companies ↔ insurance companies ↔ logistics infrastructure facilities ↔ other participants in the transport process (stevedoring, surveying companies)

Source: compiled by the authors.

Table 2. Matrix of interests and goals of participants in the transport services market, provided by smart contract technology

Interests and goals	Transport company	Transport services client	Other participants
Increasing the company's competitiveness in the transport services market	+		
Reducing cargo delivery times		+	
Timely payment for transport and related logistics services			+
Increasing the volume of provided transport and related (logistics, information and other) services	+		+
Increasing the reliability of the transportation process		+	
Expansion of the customer base	+		+
Transparency of procedures for calculating and collecting fees for services rendered		+	
Transparency of procedures for calculating payments and fines during the execution of the contract		+	+
Reducing the volume of claims, the volume of claims work	+		
Transparency of control procedures performed by the transport company		+	
Information support for the transportation process		+	

Source: compiled by the authors.

It should be noted that two smart contract models can be implemented in transport companies: hybrid and ideal. The hybrid model defines a smart contract as an element that complements the traditional contract system and acts as:

- a means of verifying the fulfillment of contract terms, confirming the occurrence of significant events for further recording in the blocks of the distributed registry;
- a set of automatically executed blocks within the traditional contract system, i.e.

used in individual elements of the transport infrastructure.

The "ideal" model describes a smart contract as self-executing using computer contract algorithms.

As a result of the study, factors and conditions for the successful implementation of smart contract technology in the logistics activities of a transport company were identified (Figure 2).

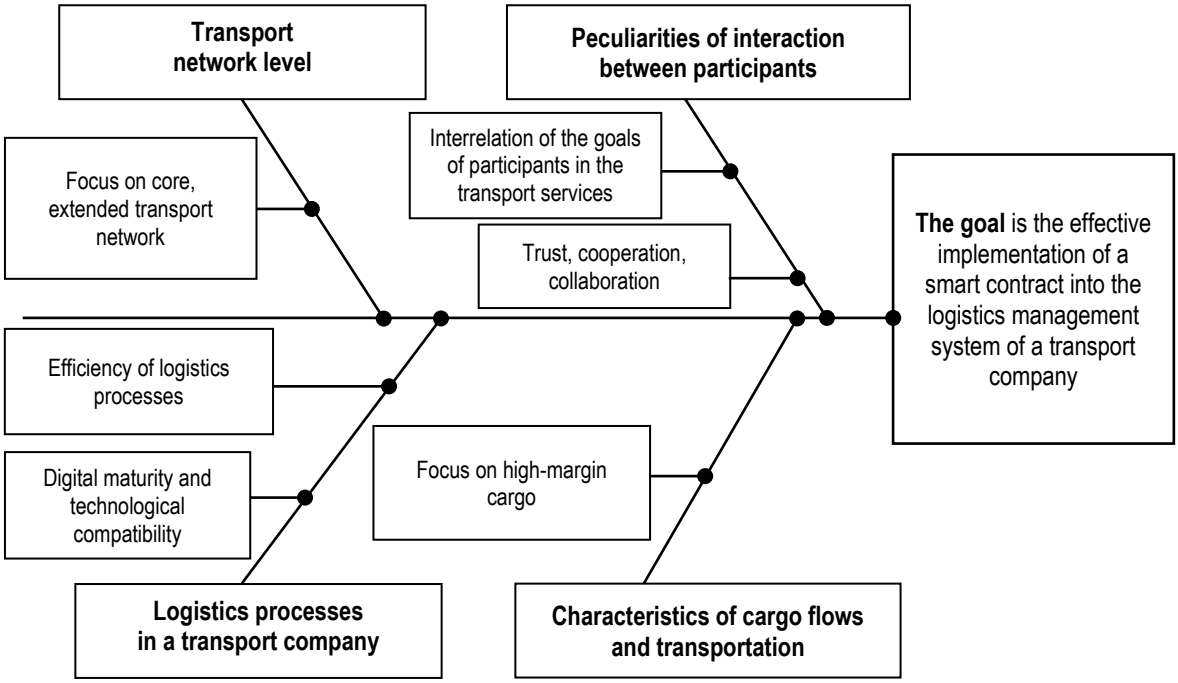

Figure 2. Factors and conditions for the successful implementation of smart contract technology in the logistics activities of a transport company
Source: constructed by the authors using the Ishikawa diagram.

The following are proposed to be considered as alternative scenarios for the transition to smart contract technology:

1) a "soft" transition scenario, which consists of a consistent increase in the functionality of the "smart" contract model, initially considered as a means of recording events confirming the fulfillment of contract terms (mainly time triggers) through the automation of the execution of individual blocks (subprocesses, elements of the transport network, etc.) to further full automation of the end-to-end logistics process. The scenario allows you to practice the technology of recording events on the existing critical information infrastructure, assess the possible risks from the automation of the fulfillment of obligations under contracts;

2) a scenario for the development of a digital supply chain. The main feature is that the "ideal" model is adopted as a working option from the initial stages of the transition. At the same time, in order to reduce the risks associated with the transition to a smart contract, implementation should begin with the most mature sub-processes, previously identified at the pre-project stage.

Conclusions. Summarizing the main provisions of the completed study, the following conclusions can be made.

The objective prerequisites for the transformation of logistics business process management, due to the differentiation of forms of interaction between key participants in the logistics chain (network) that generate added value, the development of digital technologies, and more active use of virtual interaction methods, form the main

directions of promising changes: building relationships with clients on the principles of customer focus [51; 52], based on increasing the availability of services in the logistics chain (network), information transparency and high trust between participants; development of network forms of interaction; the formation and development of a set of subsystems that support the processes of managing interaction between participants using the potential of digital technologies.

The transition to smart contract technology significantly changes the requirements for both the composition of trigger events and the means of recording them. A prerequisite for the implementation of smart contract technology is the creation of an information infrastructure that allows autonomously, without human intervention, recording the fact of the occurrence of trigger events using automated systems and digital data transmission means. Smart contracts are a new form of concluding contractual agreements with the most detailed description of the terms of the contract, formalized in the form of a program code without the possibility of its subsequent adjustment. It is obvious that over time, smart contract technology will be increasingly used in the work of service enterprises, including transport and logistics. This is due to the fact that such solutions significantly simplify and speed up existing business processes of logistics activities, and also contribute to the creation of a transparent and controllable system of interaction between participants in the service market at all stages.

Contractual relations in the management system are built on the principles of enhanced horizontal integration of participants in the value chain, focused on increasing the added value of products in the overall business system. Smart contracts act as an element of regulation of the logistics system, combining business relations of the parties and technological aspects of the movement of inventory and intangible assets that have a quantitative expression and are therefore amenable to logistics management. At the level of the physical control loop, regulation of material and service (servicing) flows of product movement is implemented. Within the virtual control loop, information and financial flows accompanying the movement of products are controlled. End-to-end continuous flow control, combining the provision of factory performance levels and business process efficiencies specified in the control system, corresponds to current trends in the digitalization of manufacturing and service businesses that are financially interested in accelerated asset turnover and, as a result, in reducing the duration of operational cycles for the manufacture and delivery of products. Connecting flows of various natures to a smart contract creates the necessary conditions for the synthesis of an omnichannel environment, communications in which allow all parties to the logistics process to interactively monitor the parameters of the supply chain status and plan intra-company business activities and inter-company interactions with the consumer community. Omnichannel logistics and supply chains ensure minimal delays in the response of the logistics management system to consumer demand and to the offers of service providers, the dynamics of which are predicted by the business planner taking into account the business capabilities of all participants in the smart contract, correlated with the conditions of the infrastructural and institutional uncertainties of the market environment for the production and distribution of digital or physical products.

Prospects for further research lie in the theoretical and methodological substantiation of the provisions and the development of a strategy for the digital transformation of the logistics processes of a transport company when switching to smart contact technology.

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MICRO-FULFILLMENT NETWORKS AS AN INFRASTRUCTURAL RESPONSE TO THE CHALLENGES OF QUICK E-COMMERCE IN WARTIME CONDITIONS

Mariia Hryhorak, Olga Karpun, Marharyta Sinaiko. «Micro-fulfillment networks as an infrastructural response to the challenges of quick e-commerce in wartime conditions». *The article theoretically substantiates, for the first time, the feasibility of deploying micro-fulfillment center (MFC) networks as an adaptive logistics infrastructure in emergency situations, particularly martial law. A conceptual model for the formation of an MFC network is proposed, which considers key factors such as spatial demand, the availability and accessibility of resources, as well as potential risks that may arise during crisis situations. The developed model allows for a more efficient distribution of logistics flows and optimization of infrastructure to achieve high operational efficiency under conditions of limited resources.*

Particular attention in the article is paid to the systematization of challenges faced by quick e-commerce in urban environments during wartime, specifically issues related to infrastructure damage, disruptions to transport routes, and the need to ensure uninterrupted delivery of goods in areas where instability is observed

due to the war. It is determined that MFC networks have significant potential in enhancing the resilience of logistics systems, providing quick and efficient access to goods even in challenging conditions.

An important element of the research is the application of the K-means clustering algorithm to model optimal locations for MFCs in crisis situations, which is a novel approach in the study of urban logistics. Based on the analysis of spatial data and demand, the algorithm allows for the identification of the most advantageous locations for MFCs, ensuring high delivery speed and minimization of logistics costs. This tool enhances the efficiency of logistics systems management, making them more adaptive to the rapidly changing conditions of war or emergency situations.

***Keywords**:* quick e-commerce, urban logistics, last mile logistics, fulfillment service, micro-fulfillment centers, micro-fulfillment center network

Марія Григорак, Ольга Карпунь, Маргаріта Сінайко. «Мережі мікрофулфілменту як інфраструктурна відповідь на виклики швидкої е-комерції в умовах війни». *У статті вперше на теоретичному рівні обґрунтовано доцільність розгортання мереж мікрофулфілмент-центрів (МФЦ) як адаптивної логістичної інфраструктури в умовах надзвичайних ситуацій, зокрема воєнного стану. Запропоновано концептуальну модель формування мережі МФЦ, яка враховує ключові фактори, такі як просторовий попит, наявність і доступність ресурсів, а також потенційні ризики, що можуть виникнути під час кризових ситуацій. Розроблена модель дозволяє більш ефективно розподіляти логістичні потоки та оптимізувати інфраструктуру для досягнення високої оперативності в умовах обмежених ресурсів.*

Особливу увагу в статті приділено систематизації викликів, з якими стикається швидка е-комерція в міському середовищі під час війни, зокрема проблемам, пов'язаним з пошкодженнями інфраструктури, порушеннями транспортних маршрутів і необхідністю забезпечення безперебійної доставки товарів у зонах, де в умовах війни спостерігається нестабільність. Визначено, що мережі МФЦ мають значний потенціал у підвищенні стійкості логістичних систем, забезпечуючи швидкий і ефективний доступ до товарів навіть у складних умовах.

Важливим елементом дослідження є застосування алгоритму кластеризації K-means для моделювання оптимальних точок розміщення МФЦ в умовах кризових ситуацій, що є новим підходом у дослідженні міської логістики. Алгоритм дозволяє на основі аналізу просторових даних та попиту визначити найбільш вигідні локації для МФЦ, що забезпечить високу швидкість доставки та мінімізацію логістичних витрат. Цей інструмент підвищує ефективність управління логістичними системами, роблячи їх більш адаптивними до швидко змінюваних умов війни чи надзвичайних ситуацій.

Ключові слова: швидка е-комерція, міська логістика, логістика останньої милі, фулфілмент-сервіс, мікрофулфілмент-центри, мережа мікрофулфілмент-центрів.

Intraduction. The growth in e-commerce has already become one of the most significant trends in the global market, and in the next decade, this sector will continue to develop due to numerous economic, technological, and social factors. Currently, over 33% of the world's population actively shops online, and the volume of the global e-commerce market has already reached $6.8 trillion [1]. According to Promodo's forecasts, by 2027, the e-commerce market volume will exceed $7.9 trillion, which is 39% more compared to today's level. We observe similar trends in Ukraine. According to Similarweb traffic estimates, over 90% of people in Ukraine use the internet, with 78% doing so daily. Therefore, the potential for online business growth is significant. In Ukraine, this figure is three times lower than in the USA and

Britain: approximately 15-20% compared to 45-50% in certain segments [2].

E-commerce has a powerful impact on the development of logistics, transforming traditional logistics models and posing new requirements for the organization of transportation, storage, and delivery processes. One of the key challenges facing logistics in the context of the rapid development of e-commerce is the need to handle a large number of small orders that require prompt picking, personalized packaging, and fast delivery to the end consumer. This fundamentally changes the nature of logistics operations, which were previously focused mainly on large batches of goods and centralized deliveries. Currently, the role of last mile delivery is growing, becoming critical in terms of both meeting customer expectations and the overall cost of logistics services. In the context of e-commerce, the requirements for warehouses and distribution centers are also changing. Modern logistics centers are transforming into high-tech facilities equipped with automated storage, sorting, and real-time tracking systems. Warehouse location is acquiring a new logic – more and more companies are creating decentralized networks of micro-fulfillment centers near major consumer markets to shorten delivery times. As numerous studies of customer expectations show, delivery speed is one of the main reasons for abandoning purchases. Therefore, the instant delivery segment, where consumers can receive their order within 15-30 minutes, is one of the fastest-growing. This indicates the need for the development of logistics infrastructure in urban environments, in particular, last mile delivery fulfillment centers, as well as the need to search for new business models for supply chains in the context of quick e-commerce.

Wartime conditions cause significant transformations in the economic, social, and infrastructural environment, which fundamentally affects logistics and consumption patterns. In this context, quick e-commerce (Q-commerce) acquires particular importance, as it can promptly provide the population with essential goods under conditions of limited access to traditional retail channels. It reduces risks for citizens by minimizing the need for physical movement and simultaneously supports the economic activity of small and medium-sized businesses through digital sales channels. Q-commerce also contributes to increasing logistics resilience: thanks to digitalization, flexibility, and the ability to scale quickly, it promptly responds to changes in the geography of demand, particularly due to population displacement or changes in supply conditions [3]. In wartime, this model stimulates the development of new logistics solutions, including micro-fulfillment centers, which allow for reducing the distance to the consumer and ensuring fast order fulfillment. Thus, quick e-commerce becomes not only an adaptive form of retail but also a tool for ensuring social stability, economic resilience, and the development of innovative logistics infrastructure.

Literature and researches review. The problematics of last mile logistics in urbanized environments have gained widespread scientific and practical interest in the context of the rapid growth of e-commerce, the increasing number of deliveries, and the burden on urban infrastructure. Foreign researchers indicate that traditional logistics approaches prove ineffective in conditions of limited space, high population density, traffic congestion, and environmental challenges characteristic of modern cities.

Among recent publications, some ideas and provisions that form the theoretical basis and justification for the relevance of the topic were used for our research. In particular, the works of contemporary authors thoroughly investigate the problems of last mile logistics in the context of the growth of e-commerce and urbanization. Special attention is paid to the implementation of sustainable solutions, such as micro-fulfillment centers, mobile pick-up points, the use of electric vehicles and cargo bicycles, as well as the application of

digital technologies to optimize routes and delivery processes.

The authors [4] drew attention to the need to study the mobility of goods in the urban environment and to develop decision support tools considering social, economic, and environmental indicators in the appropriate spatial-temporal scale using modeling methods. They substantiated that urban mobility encompasses not only commercial activities in the central areas of the city but also the transportation of people and goods in a broader context. The participation of all actors in the production and logistics chains – both public and private sectors – is critical for optimizing transport commercial activities within urban areas. Urban logistics studies the mobility of goods and services in cities to achieve an optimal balance between time, distance, and costs. These two concepts – urban mobility and urban logistics – are closely related and cannot exist without each other. Urban logistics is always an integral part of the urban mobility system. Consequently, a strategic approach to the development of urban logistics should consider the type of city, its economic and social ambitions, the professional structure of the population, demographic characteristics, and other factors that contribute to or determine the evolution of the urban environment [5].

The work [6] presents a thorough bibliometric analysis of scientific literature dedicated to urban last mile logistics in the context of omnichannel retail. This analysis showed that the largest number of publications falls on the period after 2020, which is associated with the rapid growth of e-commerce due to the COVID-19 pandemic [7] and others. The work [8] explores the connection between last mile logistics and the concept of smart cities, emphasizing the positive role of digital technologies in solving last mile problems. One of the key areas is the implementation of green technologies, including the use of electric and hybrid vehicles for delivery, which contributes to reducing CO2 emissions and improving air quality in cities. In addition, the thematic structure of research demonstrates that the concept of "sustainable development" occupies a central place in scientific discussions, but requires further development in the context of e-commerce logistics. In particular, the issues of reducing the ecological footprint, increasing energy efficiency, and implementing sustainable transport solutions remain open.

A new official publication by the World Economic Forum, prepared in collaboration with Accenture, emphasizes that the increase in traffic congestion, greenhouse gas emissions, and negative impacts on public health are among the key hidden costs associated with the intensive development of urban delivery [9]. This once again underscores the relevance of rethinking urban last mile logistics models, taking into account social and environmental consequences.

Additionally, a systematic literature review conducted in the study «Sustainable Urban Last-Mile Logistics: A Systematic Literature Review» (2023) covers 102 scientific works for the period 2016–2022 [10]. It emphasizes that the last mile is the most costly and inefficient part of the logistics chain, causing significant economic, environmental, and social external effects. The study also indicates the need to develop new urban logistics models that would take into account the principles of sustainable development and contribute to reducing the negative impact on the environment. Another study, "Sustainable and Efficient Last-Mile Delivery in Cities," prepared by the World Economic Forum in collaboration with Accenture, predicts that without intervention, emissions from deliveries in urban centers could increase by 60% by 2030 [11]. The report highlights the need to implement sustainable and innovative practices in the field of delivery, such as the electrification of vehicles, route optimization, and the use of alternative modes of transport, to improve the quality of life and support a thriving business environment.

Last mile logistics, as a component of urban logistics, focuses on the delivery of goods directly to the end consumer, which has led to a rapid increase in the number of shipments within urban areas. Today, a large number of companies deliver parcels, food, clothing, and other everyday goods in cities. Each of them faces a number of challenges due to the specifics of their operating model: whether the company specializes in certain categories of goods, whether it uses its own logistics infrastructure, whether it has its own fleet and driver personnel, etc. All these companies are simultaneously participants and factors in the problematics of last mile logistics in the urban environment – they not only ensure the execution of delivery but also experience the impact of its complexities and limitations [12].

Many researchers emphasize that the development of e-commerce exacerbates existing urban problems, particularly the growth of traffic congestion and emission levels. This requires not only managerial decisions but also technological innovations, including the implementation of urban logistics centers, micro-platforms, electric vehicles, and cargo bicycles for delivery in pedestrian and quiet zones.

One of the promising solutions is the creation of micro-hubs, which allow for the consolidation of deliveries within a specific district or street network, instead of several retail operators sending separate vehicles to the same location. Such logistics points become key nodes supported by digital tracking technologies and shared logistics tools. The integration of micro-hubs, digital platforms, and collaborative logistics models is a driving force in the transformation of urban delivery. Thanks to these approaches, cities can not only reduce traffic congestion and pollution levels but also reclaim urban space for residents, making it safer, more comfortable, and more livable.

Micro-fulfillment centers can be considered a new stage in the development of goods distribution in urban areas, which also includes storage solutions. According to [13], MFCs are small fulfillment centers located in the city center or business activity centers, functioning as forward operating bases for quick, usually online, services. Their role is extremely important for last mile logistics, as they bring the resolution point of the supply chain closer to the end consumer. They can be considered small distribution warehouses, strategically located in cities for order fulfillment, occupying much less space than traditional large retailer warehouses [14]. The authors [15] note that MFCs actively use automated or robotic movement of goods with a simultaneous combination of manual labor. They can combine traditional technologies and automation with in-store picking, while their main goal is to bring goods closer to the end consumer, which significantly increases the speed of delivery or pickup [16]. Some researchers believe that MFCs are a mobile order fulfillment system that can radically and very effectively use mobile technologies and real-time delivery solutions [17]. Thus, MFCs have 2 main components: software management systems that process online orders, and physical infrastructure, including robots that pick items from warehouse aisles and deliver them to packers or directly to the customer.

The work [18] demonstrated that the use of MFCs can become a catalyst in solving the problem of sustainable urban last mile logistics, which will contribute to reducing CO2 emissions in urban areas. This concept can help alleviate congestion in urban areas, as fewer vehicles will be needed for the delivery of goods due to the reduced distance to the consumer through the placement of MFCs in city centers and other strategic urbanized locations characterized by proximity to the end-user [19]. As a result, customers/city residents will receive a number of benefits: faster delivery, lower noise levels due to reduced congestion, fewer road accidents, and cleaner air due to reduced CO2 emissions, which may even increase their life expectancy [20]. In addition, automation and the use of new technologies in micro-fulfillment centers will help reduce order

fulfillment times, which will increase customer satisfaction and delivery efficiency. These results can be used to significantly reduce the problem of urban last mile logistics, emphasizing the importance of using micro-fulfillment centers – a solution that combines storage, consolidation, and delivery of goods to the end consumer in an efficient and perfect manner with minimal environmental impact.

It should be noted that in Ukrainian-language scientific literature, the problems of the last mile in the urban logistics system have been studied fragmentarily, that is, by individual partial indicators, and their results are presented mainly in the materials of scientific and practical conferences. Among the scientific publications whose ideas are used in this article, it is worth noting the article by Ilchenko N.B. and Kotova M.V., which summarizes a set of factors influencing decision-making regarding the organization of goods delivery in the e-commerce system [21]. Datsenko D.R. and Kunytska O.M. drew attention to the placement of logistics infrastructure facilities in cities and proposed an approach to determining the location of an urban distribution center based on the logistics stability index [22]. Oliynyk O. investigated the synergy of e-commerce and fast commerce in the food industry [23]. Sumets O. and Klymovych R. investigated the integrative effect of combining fulfillment and logistics in serving customers in the online trading system [24]. The problem of forming and developing freight flow consolidation centers in the urban environment is most fully and thoroughly researched in the works of Savchenko L.V. [25, 26, 27].

Thus, the analysis of literary sources indicates a multifaceted approach to the study of last mile logistics problems. The research covers various aspects, including the sustainable development of the urban environment, the reduction of greenhouse gas emissions, the alleviation of congestion, the improvement of the quality of life of residents, as well as the operational efficiency of delivery and the application of innovative logistics solutions – such as micro-hubs, automated pick-up points, cargo bicycles, and electric vehicles. Significant attention is paid to the implementation of digital technologies for tracking deliveries and coordinating participants in the logistics process.

However, it should be recognized that a separate important component of this topic – the formation and development of micro-fulfillment center (MFC) networks as a key last mile infrastructure – still remains insufficiently studied. MFCs play a strategic role in ensuring quick and efficient delivery in the context of the rapid growth of online trading, especially in the segment of quick (on-demand) e-commerce. Their functional significance is enhanced in the context of the need for diversified warehousing, reduced order picking times, and integration with urban logistics systems. Thus, the identified scientific gap in the study of the network organization of micro-fulfillment as the final link in the e-commerce supply chain determines the relevance and scientific novelty of this article.

Aim and objectives. Aim of the research. To substantiate the feasibility of forming micro-fulfillment center (MFC) networks as an effective infrastructural solution for ensuring the stability, flexibility, and operational efficiency of quick e-commerce logistics under conditions of military threats and urban environment limitations.

Research objectives:

1. To investigate the specifics and challenges of quick e-commerce development in wartime conditions.
2. To analyze the role and functions of micro-fulfillment centers in the logistics infrastructure of urban areas.
3. To assess the potential of MFC networks in ensuring the adaptability of logistics in crisis conditions.
4. To identify key factors for the effective planning and location of MFCs.
5. To propose a structural and functional model of an MFC network as an infrastructural

response to the challenges of quick e-commerce in wartime conditions.

Research methodology. This research employs a comprehensive methodology combining systemic, analytical, and applied approaches to substantiate the feasibility of developing MFC networks in the urban environment as an adaptive element of logistics infrastructure under martial law. Firstly, a systemic approach is used to investigate the functioning of quick e-commerce as a complex logistics system responding to external challenges. The analysis focuses on the ability of MFCs to ensure the continuity, flexibility, and speed of delivery in urbanized spaces, especially during a crisis. Secondly, case study analysis of micro-fulfillment implementation in wartime conditions is applied, particularly using examples from Ukrainian cities where the restructuring of logistics routes, the reorientation of warehouses, and the launch of local hubs took place. Thirdly, cluster analysis methods, specifically the K-means algorithm, are used to model the potential location of MFCs, considering the spatial distribution of demand, population density, risk zones, and the availability of transport infrastructure. This interdisciplinary approach allows for covering both strategic and applied aspects of forming an adaptive logistics infrastructure based on micro-fulfillment networks.

Results, analysis and discussion. Quick e-commerce (Q-commerce) is a cutting-edge model of online retail focused on ultra-fast delivery of everyday goods within 10-60 minutes after order placement. It is based on the use of micro-fulfillment centers, dark stores, and in-house or partner courier services located in close proximity to consumers in cities. Unlike traditional e-commerce, which focuses on a wide assortment and centralized warehouses, q-commerce prioritizes speed of service, relying on digital technologies, automation, and accurate demand forecasting. This model is becoming increasingly popular in the context of urbanization and changing consumer expectations. According to research by M. Bogdanova, 30 new Q-commerce companies were registered in Western Europe in 2020. One of the most striking examples is Gorillas, which managed to achieve «unicorn» status (capitalization over $1 billion) in less than a year, indicating extremely high demand from investors and users for quick, flexible, and localized logistics solutions, and one of them, called Gorillas, reached unicorn startup status in just nine months [28].

Scientific sources indicate that the «last mile» model in Q-commerce fundamentally differs from traditional e-commerce: while classic e-commerce optimizes delivery by combining several orders on one route, Q-commerce ensures point-to-point delivery of each individual order, often by an individual courier operating within a narrow micro-district. This changes the requirements for logistics infrastructure, personnel, IT systems, and route planning approaches [29]. Thus, Q-commerce forms a new paradigm of urban logistics, in which speed, flexibility, and local presence become the main competitive advantages.

Summarizing the impact of quick e-commerce on the transformation of urban logistics infrastructure and the evolution of approaches to solving the last mile delivery problem, we have systematized the main challenges and opportunities of this process. This analysis allows for a deeper understanding of how speed, technological innovations, and changing consumer expectations affect urban space and logistics practices. The presented generalization (Fig. 1) reflects the complexity and interdependence of factors shaping modern urban logistics in the context of the rapid development of Q-commerce.

Thus, the main risks associated with the development of quick e-commerce and last mile logistics concern the overloading of urban infrastructure, increased congestion, emissions, and logistics costs, as well as a lack of investment in sustainable solutions. In the context of military risks, these problems become even more complex due to

102-120
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infrastructure damage, the destruction of transport networks, disruptions in resource supply, limited access to key supply chain links, and potential security threats to logistics facilities and personnel. In addition, during wartime, problems arise with economic instability, including a decrease in consumer solvency and an increase in the number of goods requiring delivery to combat zones, which demands additional resources to ensure delivery under such conditions

Figure 1 – Generalization of influencing factors, risks and development opportunities of last mile logistics in the urban environment

At the same time, opportunities are associated with the introduction of innovative service formats, digital technologies, micro-fulfillment centers, and new models of cooperation, which can increase delivery efficiency, improve service, and reduce the negative impact on the urban environment. In addition, in wartime conditions, MFCs can become critically important for ensuring delivery to areas where traditional logistics routes are disrupted, as well as for adapting to changing conditions and ensuring the

sustainability of logistics systems in crisis situations.

In the context of these challenges and opportunities, the role of micro-fulfillment centers (MFCs) is particularly noteworthy. They are seen as a key element of an adaptive logistics infrastructure capable of ensuring prompt, sustainable, and efficient delivery in the context of the rapid development of quick e-commerce. The high density of orders, the need to deliver small batches of goods in the shortest possible time, and the need to reduce the burden on urban infrastructure and the environment – all of this necessitates new approaches to the organization of the "last mile." In this context, micro-fulfillment centers (MFCs) play a strategic role. According to the results of the study «Micro Fulfillment Centers (MFCs) – Global Strategic Business Report,» the global MFC market was valued at US$6.2 billion in 2024 and is projected to reach US$31.6 billion by 2030, growing at a compound annual growth rate (CAGR) of 31.1% from 2024 to 2030 [30].

According to the definition of foreign scientists, MFCs are small or medium-sized logistics facilities located near the consumer, which perform the functions of storing, sorting, picking, and preparing orders for shipment. Their location within urban areas allows for a significant reduction in delivery time, lower transportation costs, a decrease in the number of freight trips, and the integration of environmentally friendly vehicles, such as cargo bicycles or electric vehicles. Thus, MFCs are not only a response to logistics challenges but also a tool for improving the quality of consumer service, reducing the carbon footprint of logistics, the rational use of urban space, and supporting the sustainable development of urban mobility. Their implementation allows cities to better adapt to the needs of Q-commerce while maintaining a balance between economic efficiency, social expectations, and environmental requirements.

Let's compare micro-fulfillment with traditional fulfillment. Obviously, these two models differ significantly in scale, efficiency, and approach to e-commerce. Traditional fulfillment centers are large logistics hubs, usually located outside cities, focused on processing a large volume of orders and providing centralized storage and shipment of goods. They are efficient in terms of scaling, cost per unit, and inventory optimization but are less flexible in the context of fast delivery to the end consumer, especially in urban areas. Micro-fulfillment centers, on the contrary, are characterized by smaller sizes, decentralized location closer to the consumer, and the ability to process orders in real-time. They are better adapted to the requirements of quick e-commerce (Q-commerce), where the speed of order fulfillment – from several hours to one day – is critical. At the same time, micro-fulfillment has challenges, including a higher cost of maintenance per unit, limited storage space, and the need for accurate demand forecasting.

Table 1 presents the results of a comparative analysis of the main characteristics of fulfillment centers and MFCs as logistics infrastructure facilities for last mile delivery.

The comparative analysis in Table 1 allows for visualizing these differences, showing the strengths and weaknesses of each model, and helps in choosing the optimal infrastructural strategy depending on the business model, geographical location of customers, and the target service level.

102-120
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Table 1. Comparative analysis of fulfillment centers and micro-fulfillment centers as online order processing centers

Characteristics	Fulfillment Center (FC)	Micro-fulfillment Center (MFC)
Location	Mostly outside the city or on its perimeter	In the city or very close to consumers
Size	Large (tens of thousands of m²)	Small (200-500 m² or up to 5000 ft²)
Main function	Complex processing of large batches of goods	Fast processing of small batches of orders for last mile delivery
Delivery time	From several hours to several days	15-60 minutes (express delivery)
Type of orders processed	Large, wholesale or combined batches	Small, individual e-commerce orders
Transport logistics	Delivery is carried out by freight transport over long distances	Easy last mile delivery (couriers, electric vehicles)
Automation	High level of automation	Partial automation or compact automated solutions
Service cost	Higher due to transport costs and delivery time	Smaller due to proximity to the consumer
Flexibility	Low: orientation towards large orders	High: adapt to rapidly changing needs
Environmental impact	More emissions due to long routes	Less emissions due to reduced transportation

Source: Summarized by the author based on [16, 17, 19, 20]

The main advantages of micro-fulfillment centers (MFCs) in the quick e-commerce and last mile delivery system in the urban environment can be substantiated through several important aspects:

1. Relatively lower initial investment needs. MFCs have comparatively low capital investment requirements as they are easily integrated into existing logistics and operational processes already used for order processing. This creates opportunities for small and medium-sized businesses by providing access to innovative logistics without the need for large upfront costs. Such flexibility makes MFCs attractive to entrepreneurs seeking to grow their operations without significant financial investments in new infrastructure.

2. Optimal space utilization. Since MFCs are usually compact in size, their location in close proximity to consumers allows for significantly more efficient use of available space. This enables retailers to store a larger volume of products per unit area compared to traditional warehouses or stores. Thus, businesses can significantly improve the efficiency of their premises, optimizing rental costs and ensuring better availability of goods for consumers.

3. High level of process automation. MFCs are typically equipped with modern technologies for automating order processing, which significantly speeds up these processes. A high level of automation reduces the time required for packaging and shipping goods, as well as lowers the probability of human errors. This increases operational efficiency and allows for faster and more accurate order fulfillment, which is critical in the context of quick e-commerce.

4. Customer convenience. Locating MFCs closer to end consumers creates opportunities for faster returns, refunds, and exchanges of goods. This is important as convenience in returning goods is a significant factor in customer loyalty. Therefore, MFCs can significantly increase customer satisfaction through a simplified procedure for returns and exchanges.

5. Accelerated last mile task completion. One of the main advantages of MFCs is their ability to deliver goods with minimal delays, as these centers are located directly in urban areas where consumers live. This allows for reducing delivery times and enables same-day or delivery within a few hours after placing an order. Such speed meets the demands of modern quick e-commerce,

where delivery time is critical for meeting consumer needs.

Thus, MFCs not only ensure prompt delivery in crisis conditions but also increase the flexibility, reliability, and resilience of the entire logistics system. They are becoming an important infrastructural response to the challenges of an unpredictable environment.

Since international experience and the results of scientific research confirm the feasibility and effectiveness of creating MFCs in the urban environment to accelerate the delivery of goods sold online at the last mile stage, it is necessary to develop a methodological approach to selecting locations and forming a network of such centers.

The selection of locations for micro-fulfillment centers (MFCs) should be based on the concept of distributed warehousing, which involves not the centralization of logistics capacities in one large warehouse but the formation of a network of interconnected small warehouses evenly distributed within the urban or agglomeration area. This approach makes it possible to reduce the time and distance of delivery to the end consumer, adapt logistics flows to the high density of the urban population, and ensure greater flexibility and resilience of the logistics system.

The main characteristics of an MFC network in the context of distributed warehousing are:

1. Geographical decentralization – the presence of several warehouses evenly distributed in key areas of the city or region, which allows reducing the «last mile» time and minimizing transportation costs.

2. Functional complementarity – each MFC in the network performs a specialized or redundant function (storage, picking, cross-docking), ensuring the overall adaptability of the system to demand fluctuations and changes in consumer behavior.

3. Digital integration – the unification of MFCs into a single information system for managing inventory, orders, and delivery routes, which ensures real-time process synchronization.

4. Scalability flexibility – the ability to quickly expand or contract the network depending on seasonal peaks, marketing campaigns, or changes in the demographic distribution of demand.

5. High adaptability to urban conditions – each element of the network is designed taking into account the limitations of the urban environment (traffic, building density, zoning, availability of parking spaces), which makes such a network practical for large cities.

6. Reduced environmental impact – due to the reduction of transport legs and the possibility of using environmentally friendly modes of delivery (electric transport, bike logistics), the MFC network contributes to the sustainable development of urban logistics.

We will apply the K-means algorithm to the design of an MFC network in the urban environment, which allows for clustering geospatial data, facilitating the determination of optimal locations for MFC placement [31, 32].

The K-means algorithm for forming an MFC network works according to the following scheme:

1. The number of clusters K is determined, which corresponds to the number of MFCs in the network.

2. K initial cluster centers are randomly selected – conditional locations for the MFCs.

3. Each demand point (e.g., order or customer) is assigned to the nearest cluster center based on geographical distance.

4. For each cluster, a new center is calculated – the geometric mean of the demand points within that cluster.

5. Steps 3-4 are repeated until stabilization – when the cluster centers no longer change.

The method is based on minimizing the sum of the squared distances between each observation and the center of its cluster, that is, the function:

$$\sum_{i=1}^{N} d\left(x_i, m_j(x_i)\right)^2$$

where d – is the metric (in our case, distance); x_i – is the $i\text{-}th$ data object; and $m_j(x_i)$ – is the center of the cluster to which element x_i is assigned at the $j\text{-}th$ iteration. In this case, the cluster center will be considered the branch that is geometrically closest to the actual center of the cluster obtained from the K-means calculations.

For the practical application of the K-means algorithm, data on the location of parcel delivery points and existing fulfillment centers of the «Nova Poshta» company in the city of Kyiv were used. The geographical coordinates of each point were determined using «Google Maps» and «OpenStreetMap» services. The obtained coordinates were clustered using the standard K-means algorithm.

To determine the optimal number of clusters, a search of values from 3 to 40 was performed. For each option, the value of the objective function of the following form was calculated:

$$F(n) = intera_n + C_{CENTER} * n$$

where:

$intera_n$ – is the clustering inertia, which reflects the quality of clustering by summing the squared distances between each point and its centroid. This parameter is calculated by measuring the distance between each data point and its centroid, squaring this distance, and summing these squares for one cluster;

$\mathrm{C_{CENTER}}$ – is the cost parameter for creating a new cluster. The value $\mathrm{C_{CENTER}}=0.01$ is set, which is due to the low absolute values of the distances between objects in geographical coordinates (due to the fractional part of longitude and latitude);

n – is the number of clusters.

The calculations were automated by writing a python script, and their results are presented in Fig. 2.

Thus, the smallest value of the objective function is achieved with the number of clusters equal to 14. This means that it is advisable to form 14 main centers that can act as MFCs for the 390 existing branches of the company. Further calculations are performed taking into account this number of clusters. The visualization of the clustering results is shown in Fig. 3. On the map, the branches of the "Nova Poshta" company are marked with dots, grouped by color according to their cluster affiliation. Branches that function as cluster centers are marked with framed dots.

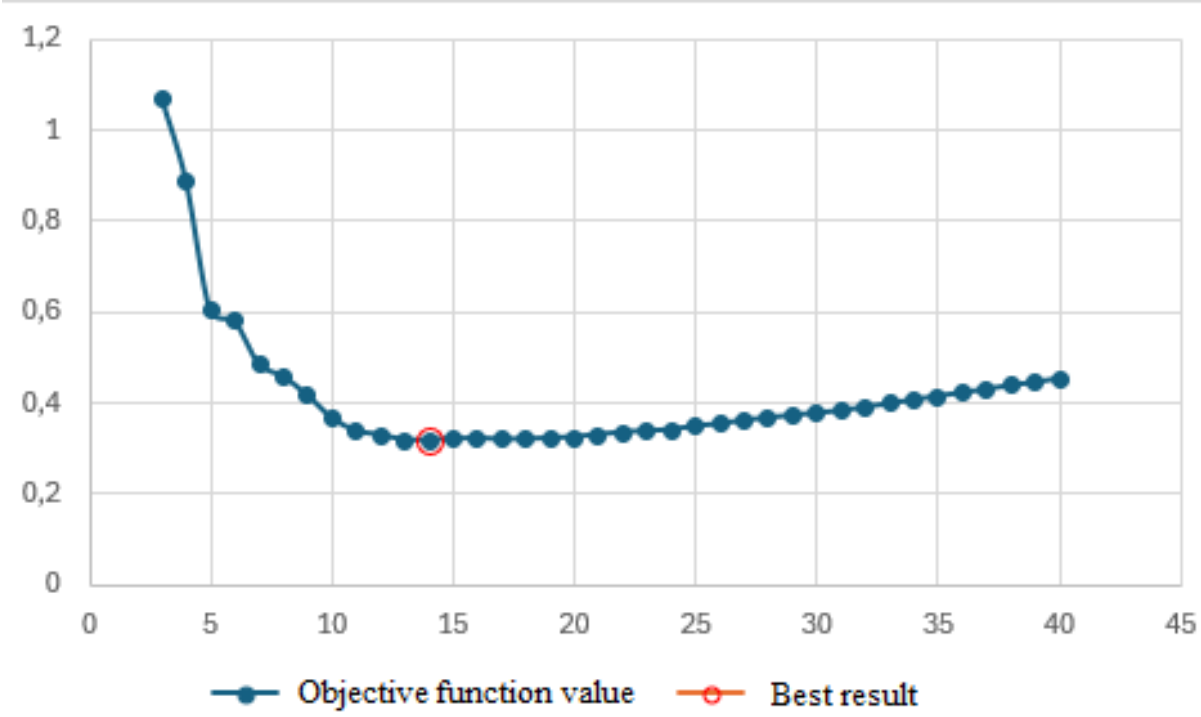

Figure 2 – Dependence of the objective function on the number of clustering points

Black lines show geographically justified connections between the central branches and their subordinate points.

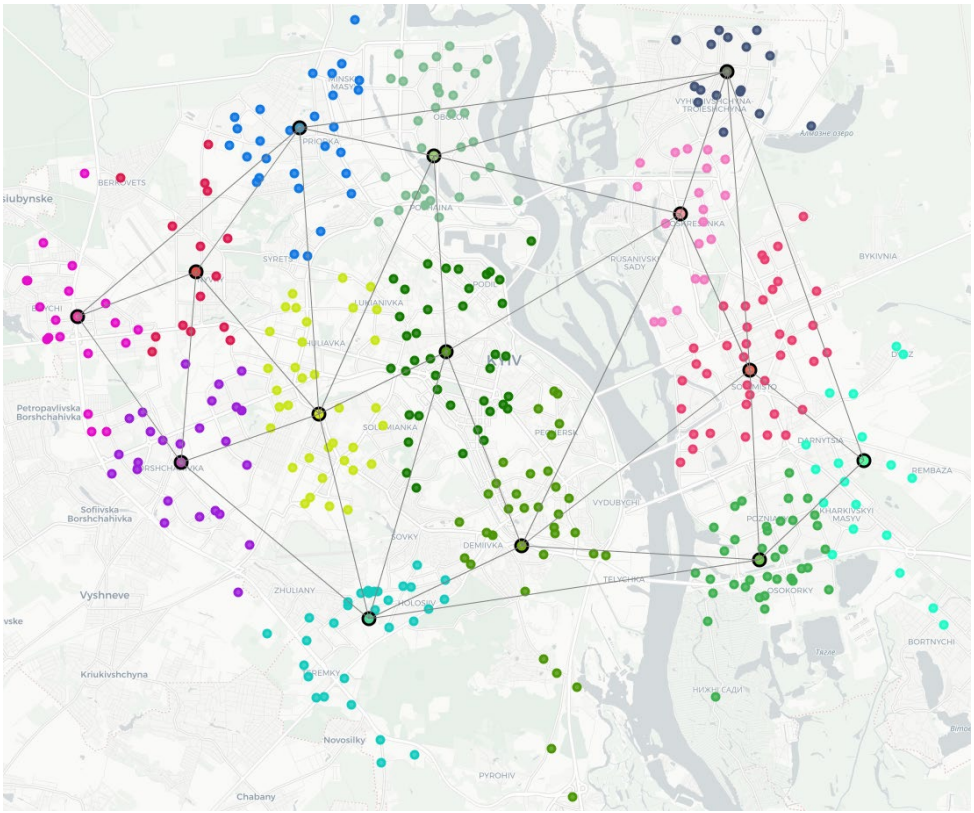

Figure 3 – Graphical representation of clusters and MFC localization points (number of clusters is 14)

Further, a detailed analysis of each of the identified clusters was conducted. For this purpose, appropriate calculations were performed for each cluster: the number of branches was determined (according to the results table obtained from the Python script), the average distance between branches within each cluster to its center was calculated, and the maximum distance from the center to the most distant branch was also determined. In addition, the table shows the coordinates of the centers of each cluster. The summarized calculation results are presented in Table 2.

The table shows that the average distance between branches in all clusters does not exceed 2.3 km, which indicates the compactness of the system. However, the main problem is the presence of local «tails» in cluster №8. Analyzing Fig. 3, it can be seen that cluster №8 (marked in light green at the bottom of the map) has an «elongated» shape along the Stolychne Highway, where five branches are quite far from each other and from other points in the cluster. A possible solution to this problem is to designate the northernmost branch as the «main» branch, which will speed up delivery to remote points. Theoretically, the number of orders at this branch will not be very large, as it will serve only a few branches, but this will reduce delivery time. For comparison, let's consider the results of the script for the case when the number of clusters is 26. The results are presented in Fig. 4.

It can be noted that most of the centers are located in the same location as the central branches of the clusters. It is also worth noting that with this number of clusters, the previously identified «problem» branches in the north are now combined into a separate cluster.

Table 2. Determination of MFC localization points in the network of parcel delivery points of the «Nova Poshta» company

Cluster number	Average distance (m)	Maximum distance (m)	Number of branches	X of the center	Y of the center
0	1666,81	4002,02	31	50,38572358	30,47109848
1	2011,31	5046,74	20	50,42511910	30,66494160
2	1935,34	3856,65	40	50,45232233	30,50143416
3	1821,72	4499,83	39	50,44775897	30,62026454
4	1585,85	3959,95	20	50,46104150	30,35731010
5	1710,54	3564,27	29	50,50806720	30,44406840
6	1349,53	3983,54	37	50,40046300	30,62392020
7	1130,91	2775,35	17	50,52201388	30,61130856
8	2239,00	7112,28	36	50,40395982	30,53104248
9	1559,38	3526,58	18	50,47223131	30,40372063
10	1724,12	3068,27	34	50,50095194	30,49676930
11	1775,98	3939,12	27	50,42474840	30,39773660
12	1971,83	3826,95	36	50,43670684	30,45182835
13	1534,27	3082,39	20	50,48662650	30,59304767

According to real data, there is also a cargo branch in this area. However, attention should be paid to significant discrepancies in the central areas of the city. In our model, 8 «main» branches are located there, while in reality, «Nova Poshta» has only 2 cargo branches. This may be due to the lower population density in these areas (data from Kyiv Statistics).

However, even with this population density, the creation of additional cargo and warehouse branches in the central areas can improve the logistics structure of «Nova Poshta». Even with the current lower population density in the historical center,

existing forecasts of tourist flows and prospects for the development of dark-store formats suggest the emergence of additional demand for same-day delivery.

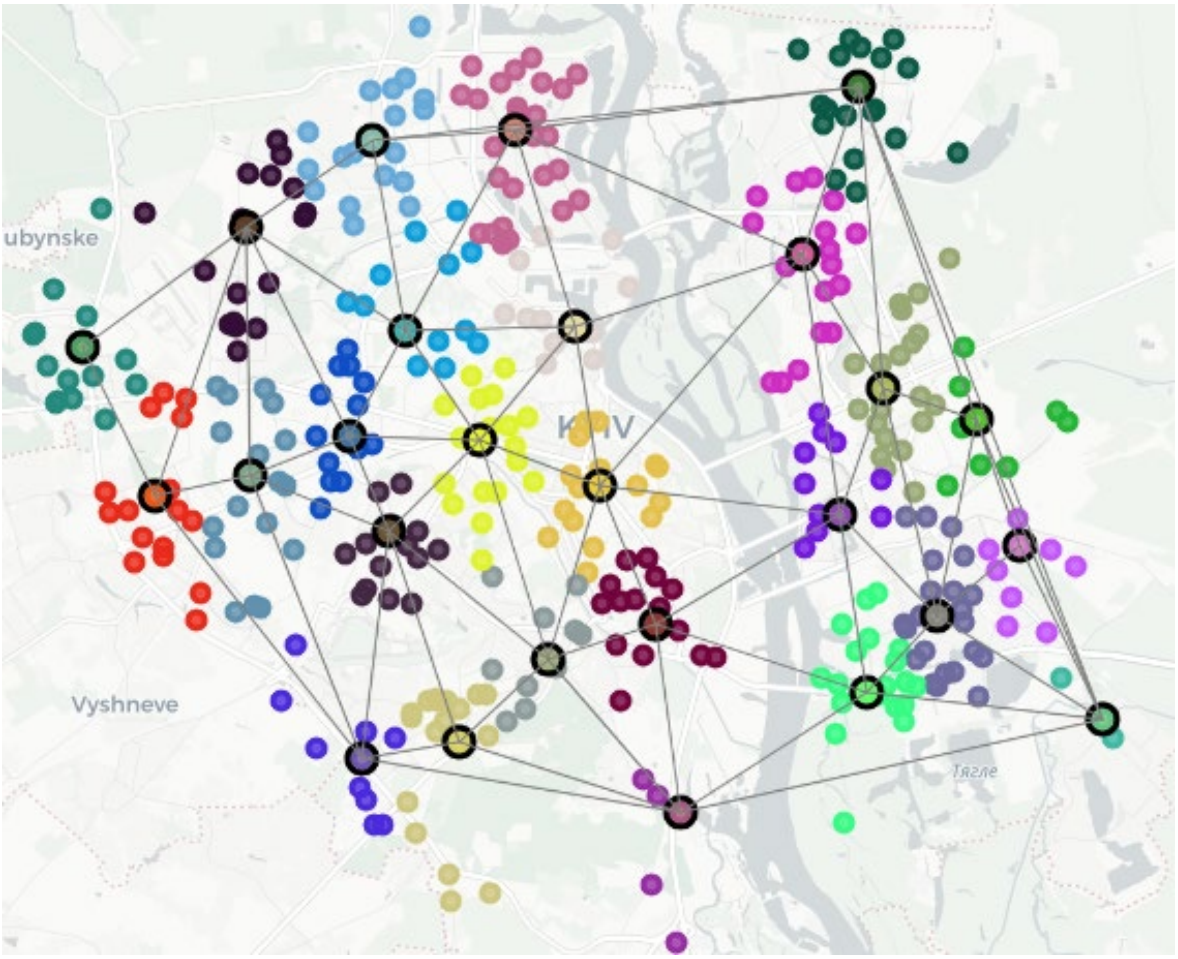

Figure 4 – Graphical representation of clusters and MFC localization points (number of clusters is 26)

The placement of two compact cargo and warehouse hubs (for example, underground parking lots or the renovation of non-residential premises) will reduce the average distance to < 1.2 km, which will reduce the number of «cross» trips between clusters № 0, 2 and 10. Modeling showed that if any of the 14 main branches are disconnected, the average distance increases by a maximum of 0.35 km, and the courier routing time increases by 6 minutes. This indicates a sufficient level of redundancy. The actual compactness of the network ($d \leq 2.3$ km with 14 clusters and ≤ 2.7 km with 26 clusters) indicates significant investments by «Nova Poshta» in dense coverage. The problem is not the number of branches, but the local geometry of the network, when a group of branches located in a «snake pattern» moves away from the center.

Overall, the calculation results show that «Nova Poshta» has an efficient system with a sufficient level of redundancy, but for further improvement, it is necessary to make changes to the geometry of the branches' location and consider the possibility of creating additional warehouse points in key areas of the city.

Conclusions. As a result of the conducted research, the effectiveness of micro-fulfillment center (MFC) networks as an adaptive logistical response to the challenges of quick e-commerce in urbanized environments and emergency situations, particularly wartime conditions, was theoretically substantiated and practically confirmed.

1. It was established that quick e-commerce plays a key role in providing the population with essential goods, especially under conditions of limited functioning of traditional supply channels. The main challenges in the development of last mile logistics in wartime conditions (infrastructural limitations, security, demand instability, etc.) were identified, and it was shown that a network approach to the placement of MFCs allows for an effective response to them. The network approach using MFCs increases the resilience of the logistics system through decentralization and risk distribution, as well as sustainable development by reducing transportation costs, environmental impact, and energy consumption through the localization of warehousing and delivery.

2. The advantages of MFCs over traditional fulfillment centers were substantiated in terms of flexibility, delivery speed, spatial proximity to the consumer, and adaptability to local risks. MFCs typically have a compact format and can be quickly opened or relocated in response to changes in demand or security threats. This allows the logistics system to adapt to a dynamic environment, unlike large fulfillment centers that require significant time and resources for launch or relocation. The location of MFCs within the city or in close proximity to residential areas significantly shortens the «last mile» of delivery. This allows for order fulfillment within a few hours, which is especially important during crisis situations when the speed of supply is critical. MFCs can serve not only as logistical service points for commerce but also as elements of humanitarian infrastructure – for the distribution of basic goods, medicines, and essentials, especially in areas where large logistics facilities have been damaged or transport movement is limited.

3. Conceptual approaches to the formation of an MFC network using the K-means clustering algorithm for selecting optimal locations, considering the spatial structure of demand, were developed. Calculations were performed using the example of a specific network of parcel delivery points of a logistics company, which allowed for verifying the practical feasibility of implementing MFCs in the urban environment.

4. Further research on the development of MFC networks as an infrastructural response to the challenges of quick e-commerce in wartime conditions should focus on a deeper study of the role of digital technologies in ensuring the efficiency of logistics processes. This includes examining the impact of technologies such as artificial intelligence, big data analytics, process automation, and the use of the Internet of Things on improving the management of MFC networks, particularly in the context of adapting to changing conditions. Digitalization allows not only to optimize delivery processes but also to increase the level of resilience and flexibility of networks, which is extremely important in crisis situations such as war. The integration of the latest digital technologies into the logistics systems of MFCs can become a key factor in reducing costs, increasing delivery speed, and adapting to unstable conditions, which opens up new opportunities for the effective functioning of e-commerce in extreme situations.

5. The research results can be used by local authorities, e-commerce operators, logistics companies, and military-civil administrations for the rapid design and development of MFC networks in cities. The proposed approaches contribute to the optimization of the «last mile», ensuring access to essential goods in emergency situations, increasing response speed, and reducing the burden on the main logistics infrastructure. The use of spatial analysis tools allows for effective planning of local logistics hubs, taking into account needs of population and environmental constraints.

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Scientific publication

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The electronic scientifically and practical journal

Electronic scientifically and practical journal “Intellectualization of logistics and Supply Chain Management” included in the list of scientific publications of Ukraine in the field of economic sciences (category "B"): **Order of the Ministry of Education and Culture of Ukraine dated October 10, 2022 No. 894 (Appendix 2)**

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