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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 discuss 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.

HRYPHORAK Mariia
Chief Editor



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METHODOLOGICAL SUPPORT FOR EVALUATING ECONOMIC EFFICIENCY FOR REALIZATION OF LOGISTICS IN AVIATION SPHERE

Volodymyr Reznik. "Methodological support for evaluating economic efficiency for realization of logistics in aviation sphere". Calculation and estimation of economic efficiency of the logistics activity is essential for further operation of every enterprise. It should be noted, that logistics composes one of the main expenditures of every enterprise. In order to optimize the operating processes of manufacturing and increase the effectiveness of the enterprise's activity, the main approach is investigated by the author. The approaches can be relied on costs correlation analysis, Direct and indirect costs are also investigated. Analysis of costs and benefits and estimation of coefficient of logistics performance index in the scale of enterprise are also investigated. All the noted methods of economic efficiency of logistics were compared and recommendations for choosing an optimal variant depends on enterprises requirements and priorities were also developed.

Keywords: Economic efficiency, neural networks, method of analysis and comparing, economic indicators, economic efficiency indicator, profitability level, economic feasibility.

Володимир Резнік. "Методичне забезпечення оцінки економічної ефективності реалізації логістики в авіаційній сфері". Розрахунок та оцінка економічної ефективності логістичної діяльності є важливим для подальшого функціонування кожного підприємства. Слід зазначити, що логістика становить одну з основних статей витрат кожного підприємства. З метою оптимізації операційних процесів виробництва та підвищення ефективності діяльності підприємства автор досліджує основний підхід. Підходи можуть спиратися на аналіз кореляції витрат, також досліджуються прямі та непрямі витрати. Також досліджується аналіз витрат і вигод та оцінка коефіцієнта логістичної ефективності в масштабі підприємства. Було порівняно всі зазначені методи оцінки економічної ефективності логістики, а також розроблено рекомендації щодо вибору оптимального варіанту залежно від потреб та пріоритетів підприємства.

Ключові слова: Економічна ефективність, нейронні мережі, метод аналізу та порівняння, економічні показники, показник економічної ефективності, рівень рентабельності, економічна доцільність

Introduction. Estimation of the economic return on logistics processes is an

integral part of the economy of the enterprise and it's operating activity, because logistics

usually accounts for a large share of financial costs and can significantly change a company's position in the market. A key method for determining this efficiency is based on comparing the costs required by logistics activities with the benefits that these activities generate. This article is the logical continuation of the number of publications, which were devoted to the evaluation of the economic efficiency of the logistics at enterprises of scientists as: Petryk I.V., Bochko O.Yu. [3, 5, 6], Molnar O.S., Paliychuk E.S., Kovtyuk Y.I. [7, 8, 9] and other Ukrainian and foreign scientists.

The purpose of the article is to provide the research of the theoretical foundation of methodological recommendation of estimation the economic efficiency of aviation logistics on the average enterprise's example. Comparing the methods of forecasting and calculation of the economy effectiveness of the enterprise and developing the recommendations of choosing the most optimal variant according to values and financial characteristics of the enterprise.

Presentation of the main results.

Methodological support for evaluating economic efficiency for realization of logistics in aviation sphere

Evaluating how economically effective a company's logistics processes are constitutes a crucial aspect of overall enterprise economy, business administration, given that transportation and warehousing expenditures frequently represent a substantial portion of overheads and possess the capacity to greatly influence market standing.

The evaluation framework centers on several vital components: expenditure related to moving goods, warehousing, managing freight, administrative overhead, and various supplementary logistical activities. Conversely, it also accounts for the income stemming from optimized logistical performance. Expenses are categorized as either immediate (such as fuel expenditure or leasing warehouse space) or deferred (for

instance, financial impacts from failing to meet scheduled deliveries, expenses linked to surplus stock, etc.) [1-4]

According to observations made by A. Suleymanov in 2021, various techniques exist for gauging the economic effectiveness of logistics operations. Specifically, the cost-benefit analysis stands out as a highly prevalent and readily graspable technique, enabling organizations to straightforwardly juxtapose the aggregate expenditures associated with logistics functions against the resultant gains. This particular methodology proves advantageous for preliminary evaluations and making swift, near-term determinations. Nevertheless, its primary drawback lies in its failure to incorporate non-monetary advantages, for instance, enhancements to a company's standing or a superior customer journey.

Modern artificial neural networks represent a powerful instrument capable of handling substantial volumes of information and accounting for intricate dependencies among various factors. Their utility shines particularly brightly within fluid market environments that necessitate immediate, up-to-the-minute data interpretation. Nevertheless, deploying these systems brings with it considerable demands on computational power and necessitates personnel possessing the requisite technological expertise.

The logistical performance indicator offers a rapid gauge of how effectively logistics operations are functioning, employing a straightforward calculation comparing revenue against expenditures. This approach proves particularly handy for swift evaluations when achieving a result promptly takes precedence over detailed scrutiny. Nevertheless, its scope is restricted because it fails to incorporate variables originating externally, like shifts in market dynamics or broader economic climates. Conversely, employing economic and mathematical simulation techniques delivers superior forecast precision and facilitates the streamlining of logistical workflows.

For further investigation and more concrete analysis the Table of comparing of the evaluation method of economic efficiency is performed by the author.

Table 1. Comparison of methods for assessing the economic efficiency of logistics

Estimation method	Advantages	Disadvantages
Analysis of loses and benefits	Clearance of the results, absence of difficulties during the application	Financial benefits cannot be taken into account
Logistics coefficient indicator	It is applicable for rapid results evaluation	Internal factors cannot be taken into account
Economy and mathematical modelling	It has the possibilities of being optimized, higher accuracy of forecasting	Difficulties in model construction, requiring complex database
Neural network	Ability to process large amounts of data, taking into account complex relationships	High requirements for computing resources, need for specialized skills

Source: Developed by the author.

Consequently, selecting the appropriate technique for gauging the economic viability of logistics operations is contingent upon the organization's distinct requirements, the resources at its disposal, and the required granularity of the investigation. Straightforward approaches, like evaluating costs against benefits or employing performance metrics, work well for rapid evaluations, whereas techniques such as econometric modeling or employing neural networks offer greater efficacy for intricate and protracted.

To evaluate performance, a composite metric is employed, merging economic, functional, ecological, and societal dimensions of supply chain functions. Specifically, the Logistics Performance Index (LPI), tailored for the air transport sector, might incorporate metrics like the swiftness of freight handling, adherence to green guidelines, and cost-effectiveness. Following this performance appraisal, avenues for improvement are pinpointed, such as implementing mechanized systems for freight movement, refining stock control methods, or streamlining transport pathways. These suggestions, derived from the collected evidence, aim to resolve critical constraints hindering the smooth functioning of logistics frameworks.

From the outset, establishing a set of crucial performance metrics that capture the entirety of logistical operations is paramount. These metrics specifically encompass expenditure, the timeframe required for logistics tasks, the standard of service delivery, and ecological considerations. Expense analysis should cover operational overhead, fuel expenditures, costs associated with aircraft upkeep, storage fees, and customs processing charges. Time-related metrics evaluate the length of time needed for freight handling, the rapidity of transport, and compliance with established timetables. Service excellence is evaluated by gauging customer contentment levels, the frequency of service disruptions, and instances of lost freight. Pertaining to environmental impact, metrics should track the amount of carbon dioxide released and overall energy utilization [5-10].

Contemporary digital instruments, including transport management systems (TMS) and warehouse management systems (WMS), serve the purpose of gathering and refining information. Information pertaining to expenditures, throughput, established pathways, and the client roster undergoes meticulous scrutiny to facilitate sound administrative choices. This process yields an exhaustive examination of logistical

operations, forming the foundation for subsequent simulation [11].

Simulating logistics flows necessitates scrutinizing diverse hypothetical situations, particularly those factoring in shifts in market demand, meteorological factors, and regulatory shifts. A crucial phase involves deploying a cost-benefit evaluation, which furnishes an appraisal of the financial viability associated with logistical activities. This

methodology enables the quantification of the aggregate expenses incurred during the execution of the logistics chain and their comparison against the advantages secured, for instance, augmented earnings, quicker fulfillment durations, or enhanced patronage contentment.

For deeper analysis and complex forecasting the results, the Table 2 was developed by the author.

Table 2. Visualization of key indicators of economic efficiency of logistics in the aviation industry

Category:	Indicator	Units of measurement	Goal and meaning
Economic indicators	Fuel costs	UAH per tones per kilometer	Minimization of costs on transportation
	Operational costs	UAH per year	Reducing of general costs
	Profitability level	%	Profitability increment
Time indicators	Average delivery time	hours	Reducing the transportation time
	Cargo handling time	hours	Optimization of cargo handling processes (loading and unloading)
Quality indicators	Level of customer's satisfaction	%	Increasing of quality of servicing
	Share of timely delivered cargo	%	Following the schedule of delivery
	Frequency of loses and damages of cargo	Cases per year	Reducing the incidents number
Ecological indicators	Volume of CO ₂ emissions	Kg/tonnes * kilometer	Reducing the negative effects
	Energy consumption	mJ/per year	Increasing the efficiency of the energy
Composite indicators	Logistics performance indicator (LPI)	Points	Complex estimation of the logistic system efficiency
	Economic advisability of the logistics processes	UAH per year	Maximization of financial benefit from logistics

Source: developed by the author

The formalization of the methodology for assessing the economic efficiency of logistics in the aviation industry consists in developing an integrated approach that takes into account the economic, operational and environmental aspects of airline activities.

In order to systematically evaluate how logistics functions economically in air transport, one must establish a comprehensive framework. This requires

devising a unified methodology that simultaneously considers the financial performance, the operational execution, and the ecological footprint associated with an airline's entire scope of work.

For further understanding of the principles of estimation of the economic efficiency, the evaluation example is represented by the author.

1) Integral Efficiency Indicator (IEI)

$$IEI = \sum_{i=1}^n W_i \cdot P_i$$

where:

W_i – weighting factor of the i -th indicator (defined by expert judgment or based on the company's strategic priorities);

P_i – standardized value of the i -th indicator;

n – number of indicators included in the analysis.

2) Calculation of Standardized Values P_i

Standardization is applied to transform indicators with different units of measurement into a unified scale [0;1].

2.1. For maximizing indicators (higher values indicate better performance)

$$P_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

2.2. For minimizing indicators (lower values indicate better performance)

$$P_i = \frac{X_{\max} - X_i}{X_{\max} - X_{\min}}$$

where:

X_i – actual value of the indicator;

X_{\min}, X_{\max} – minimum and maximum values of the indicator within the analyzed period or sample.

Mandatory methodological rule

To ensure the validity of the standardization procedure, the following condition must be satisfied:

$$X_{\max} \neq X_{\min}$$

If $X_{\min} = X_{\max}$, the indicator shows no variability and must be excluded from the analysis or replaced with an alternative

indicator, as standardization would otherwise result in division by zero and distort the integral assessment.

3) Selection of Indicators for Analysis

Economic indicators

1. Cost of transportation (C_{tr}), UAH/t – *minimization indicator*.
2. Operational profitability (R_{oper}), % – *maximization indicator*.
3. Investment payback period (T_{inv}), years – *minimization indicator*.

Operational indicators

4. Cargo processing time (T_{pro}), hours – *minimization indicator*.
5. Capacity utilization rate (R_{ut}), % – *maximization indicator*.

Environmental indicators

6. CO₂ emissions per 1 ton of cargo (CO₂), kg/t – *minimization indicator*.
7. Share of energy-efficient technologies used (E_{energ}), % – *maximization indicator*.

4) Weighting Factors W_i

Weighting factors are assigned according to the company's strategic priorities. An example distribution is:

Economic indicators – 50%
 Operational indicators – 30%
 Environmental indicators – 20%
 Weight normalization condition

$$\sum_{i=1}^n W_i = 1$$

The total weight of each group is distributed proportionally among the indicators within that group.

5) Step-by-Step Algorithm for Applying the Methodology

Step 1. Indicator definition

Select relevant economic, operational, and environmental performance indicators.

Step 2. Data collection

- Collect actual values X_i for the reporting period.
- Determine X_{min} and X_{max} for each indicator.

Step 3. Standardization

Calculate standardized values P_i using the appropriate formula for maximizing or minimizing indicators.

Step 4. Assignment of weighting factors

Define weighting factors W_i in line with strategic priorities and verify $\sum W_i = 1$.

Step 5. Calculation of the integral indicator

$$IEI = \sum_{i=1}^n W_i \cdot P_i$$

Step 6. Results analysis

- Interpret the obtained IEI value.
- Compare results with previous periods and/or competing companies.

Step 7. Formulation of recommendations

Based on the contribution of individual indicators and their weights, identify weaknesses and develop measures to improve overall efficiency.

Table 3. Calculation of standardized values of logistics efficiency indicators in the aviation industry taking into account weighting factors for further convenience and understanding

Indicator	Means (X_i)	X_{min}	X_{max}	Standartd means (P_i)	Weight (W_i)
C_{tr}	250	200	400	0.75	0.2
P_{oper}	20%	10%	30%	0.5	0.3
CO_2	50	30	80	0.67	0.1
T_{pro}	3	2	5	0.33	0.2
R_{ut}	80%	50%	90%	0.75	0.2

Source: Developed by the author.

Next step is the calculation the integral performance indicator by using the formula

$$IEI = \sum_{i=1}^n W_i \cdot P_i$$

Substituting the calculated weighted standardized values into the formula:

$$IEI = \sum_{i=1}^n W_i \cdot P_i = 0.15 + 0.15 + 0.067 + 0.067 + 0.15$$

$$IEI = 0.584$$

The obtained value of the integral efficiency indicator equals 0.584, which reflects the aggregated level of economic and operational performance based on the selected indicators and assigned weighting factors.

In our case, this result means that the effectiveness requires to be improved, at current it is at the average level. There are the following steps for further increasing the efficiency, such as:

Deployment of novel technologies.

Current inventive solutions are a principal element in streamlining logistics. Mechanization of logistics procedures, specifically via introducing supply chain management (SCM) suites and analytical frameworks, permits considerable performance gains.

Streamlining of logistics procedures.

Rationalizing logistics activities leads to a considerable lowering of expenses. A review of current freight transport paths permits minimizing the span and delivery duration, thus cutting down on fuel and vehicle running charges.

Personnel instruction. Efficient logistics administration is unachievable without capable employees able to adjust to novel circumstances and methods.

Conclusions. The implementation of these recommendations will allow aviation enterprises to reduce operating costs, improve the level of customer service and ensure competitive advantages in the conditions of dynamic market changes. It is also worth noting that the economic efficiency of logistics operations in the aviation industry is formed under the influence of a number of internal and external factors. Internal factors are related to the organization of the enterprise's work, its resources and technologies. In particular, one of the key factors is the organizational structure of the enterprise. A clear division of responsibilities between departments, coordination of actions and an effective management system allow achieving high efficiency in work, reducing the likelihood of errors and improving the quality of customer service. Continuous improvement of personnel knowledge in the field of advanced logistics practices, the use of breakthrough tools and electronic systems ensures their increased efficiency. Additionally, training programs focused on the implementation of changes will allow the team to more easily perceive changes and more successfully implement the latest developments into routine work processes.

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CONCEPT OF ENERGY EFFICIENCY OF URBAN TRANSPORT AND LOGISTICS SYSTEMS

Viktoriia Nykonchuk. «*Concept of Energy Efficiency of Urban Transport and Logistics Systems*».

The article presents theoretical and applied aspects of forming a concept of energy efficiency for urban transport and logistics systems under conditions of urbanization and increasing energy challenges. It reveals the essence of the key principles of energy efficiency, conceptual approaches to assessing energy consumption in urban transport, as well as the features of digitalizing transport processes and implementing integrated mobility management. The study examines the possibilities of using balanced integrated indicators to monitor the energy performance of urban mobility and outlines directions for reducing transport losses and improving resource efficiency. A comprehensive concept of energy efficiency is proposed, encompassing five strategic dimensions: technical (transport electrification and development of charging infrastructure), managerial (digital mobility platforms and intelligent traffic management systems), economic (incentive mechanisms for energy-saving transport), social (shaping new models of travel behavior), and institutional (establishing a municipal transport energy management center). The results may be used by local governments, transport operators, and educational institutions in developing policies for energy independence, green logistics programs, and strategies for climate-neutral mobility in Ukrainian cities.

Keywords: energy efficiency, transport and logistics system, urban mobility, sustainable development, transport digitalization, electric transport, green logistics.

Вікторія Никончук «Концепція енергоефективності транспортно-логістичних систем міста». У статті представлено теоретичні та прикладні аспекти формування концепції енергоефективності транспортно-логістичних систем міста в умовах урбанізації та зростання енергетичних викликів. Розкрито зміст основних принципів енергоефективності, концептуальні підходи до оцінювання енергоспоживання міського транспорту, особливості цифровізації транспортних процесів та інтегрованого управління мобільністю. Досліджено можливості застосування збалансованих інтегрованих показників для моніторингу енергетичної ефективності міської мобільності, а також окреслено напрями зниження транспортних втрат та підвищення ресурсної результативності. Запропоновано комплексну концепцію енергоефективності, що включає п'ять стратегічних напрямів: технічний (електрифікація транспорту, розвиток зарядної інфраструктури), управлінський (цифрові платформи мобільності, інтелектуальні системи руху),

економічний (механізми стимулювання енергоощадних перевезень), соціальний (формування нових моделей транспортної поведінки населення) та інституційний (створення міського центру енергоменеджменту транспорту). Отримані результати можуть бути використані органами місцевого самоврядування, транспортними підприємствами та закладами освіти під час розроблення політик енергетичної незалежності, програм «зеленої логістики» та стратегій кліматично нейтральної мобільності в українських містах.

Ключові слова: енергоефективність, транспортно-логістична система, міська мобільність, сталий розвиток, цифровізація транспорту, електротранспорт, «зелена логістика»

Introduction. The development of transport and logistics systems in modern cities is one of the key factors influencing the state of the environment, the level of energy consumption, and the quality of life of the population. According to the United Nations Environment Programme, the transport sector consumes up to 25% of global energy resources and generates about one quarter of total CO₂ emissions. Under conditions of rapid urbanization, increasing traffic volumes, and rising motorization rates, improving the energy efficiency of urban transport is becoming a strategic priority.

Traditional models of transport organization, based on the dominance of private vehicles and the use of fossil fuels, lead to increased energy costs, noise pollution, congestion of urban road networks, and the deterioration of the ecological condition of cities. Therefore, modern urban transport and logistics systems must focus on balanced, energy-efficient, and environmentally safe solutions that combine technological innovations, digital traffic management tools, and changes in mobility behavior.

The development of a concept for the energy efficiency of a city's transport and logistics system is an important research direction that integrates technical, economic, managerial, and social approaches. Its implementation will support the principles of green logistics, reduce energy consumption, decrease greenhouse gas emissions, and improve the quality of the urban environment.

Despite the existence of individual sustainable transport initiatives, most Ukrainian cities still lack comprehensive

approaches to energy management in transport systems. The absence of an integrated energy efficiency concept leads to inconsistent decisions, inefficient fuel use, and insufficient implementation of digital mobility management tools.

The relevance of the problem is reinforced by the high share of private transport, the depreciation of vehicle fleets, the absence of an integrated logistics system for transport operations, and the low level of energy monitoring. These factors highlight the need to develop a scientifically grounded concept of energy efficiency for urban transport and logistics systems, aimed at reducing energy consumption and improving environmental performance.

The aim of the study is to develop a scientifically justified concept of energy efficiency for a city's transport and logistics system, focused on reducing energy consumption, optimizing traffic flows, and minimizing the negative environmental impact of transport.

To achieve this aim, the following tasks are defined:

- to analyse the current state of the transport system and the structure of its energy consumption (using the city of Rivne as a case study);
- to identify the main factors influencing the energy efficiency of urban transport;
- to conduct a SWOT analysis of the transport and logistics system of the city;
- to propose a conceptual model for the energy-efficient development of the transport system.

Analysis of recent research. Issues of energy efficiency in urban transport and

logistics systems have been explored in the works of Ukrainian scholars such as S. Smerichevska (2025), O. Melnyk, L. Chorna, and others [14, 17, 18]. These studies focus on improving the transport and logistics infrastructure of Ukrainian cities, enhancing the efficiency of energy resource use, and implementing innovative technologies in urban transport systems.

Smerichevska examines conceptual models for the restoration and modernization of logistics infrastructure based on the principles of sustainable development, while Chorna investigates approaches to ensuring energy efficiency in transport enterprises, emphasizing technological modernization of the vehicle fleet and optimization of transport operations. Other Ukrainian researchers analyze the potential for logistics digitalization, the integration of smart transport systems, and the development of urban logistics hubs.

Overall, domestic publications provide a conceptual foundation for adapting global approaches to the context of Ukrainian cities, although they highlight the limited number of practical case studies and the shortage of empirical data required for quantitative assessment of energy efficiency.

Among international scholars, the energy efficiency of transport and logistics systems is addressed in the works of P. Golinska-Dawson [6], F. Russo [7], C. Navarro [11], C. Andruetto [10], as well as in reports by the World Economic Forum [8] and ICLEI [9]. These studies focus on shaping concepts of sustainable urban logistics systems that integrate energy-efficient technologies, digital solutions, and institutional management mechanisms.

Golinska-Dawson analyzes the introduction of micro-depots, last-mile electrification, and digital routing solutions that reduce energy consumption and harmful emissions. Russo proposes modeling approaches to assessing energy flows in urban logistics, while Navarro and Andruetto explore practical aspects of implementing

energy-efficient solutions in specific European cities.

A study published in *Nature Communications* [13] reveals a correlation between transport system energy consumption and the scale and density of urban areas, providing a deeper understanding of the functioning patterns of logistics in different types of urbanized environments.

The main focus areas of contemporary international research include the integration of electric transport, digital technologies (IoT, artificial intelligence, big data), and consolidation logistics centers into urban transport infrastructure to improve energy efficiency. Additionally, strong emphasis is placed on the role of public policy and urban planning in creating favorable conditions for implementing energy-saving projects.

Results of experimental studies.

1. General Characteristics of the Transport System of Rivne

Rivne is a typical medium-sized Ukrainian city characterized by high traffic density and compact urban development. The main transport corridor, Soborna–Kyivska Street, accommodates the majority of trips within the city while simultaneously generating the highest level of air pollution. According to the Safe City study, traffic intensity along this route exceeds 250 vehicles per hour, with diesel-powered vehicles prevailing [1, 3].

Other major arterial streets of citywide significance that carry the primary transport load and provide connections to the external road network include Dubenska, Sichovykh Striltsiv, Mitskevycha, Chervonoia, Chornovola, Karnaukhova, Stelmakha, Rivnenska, Knyazya Volodymyra, and Mlynivska Streets (Fig. 1). The total length of the city's arterial street network is 80.6 km, of which 35.2 km are streets of citywide importance. The density of the urban street network is 2.2 km/km² [2, 4].

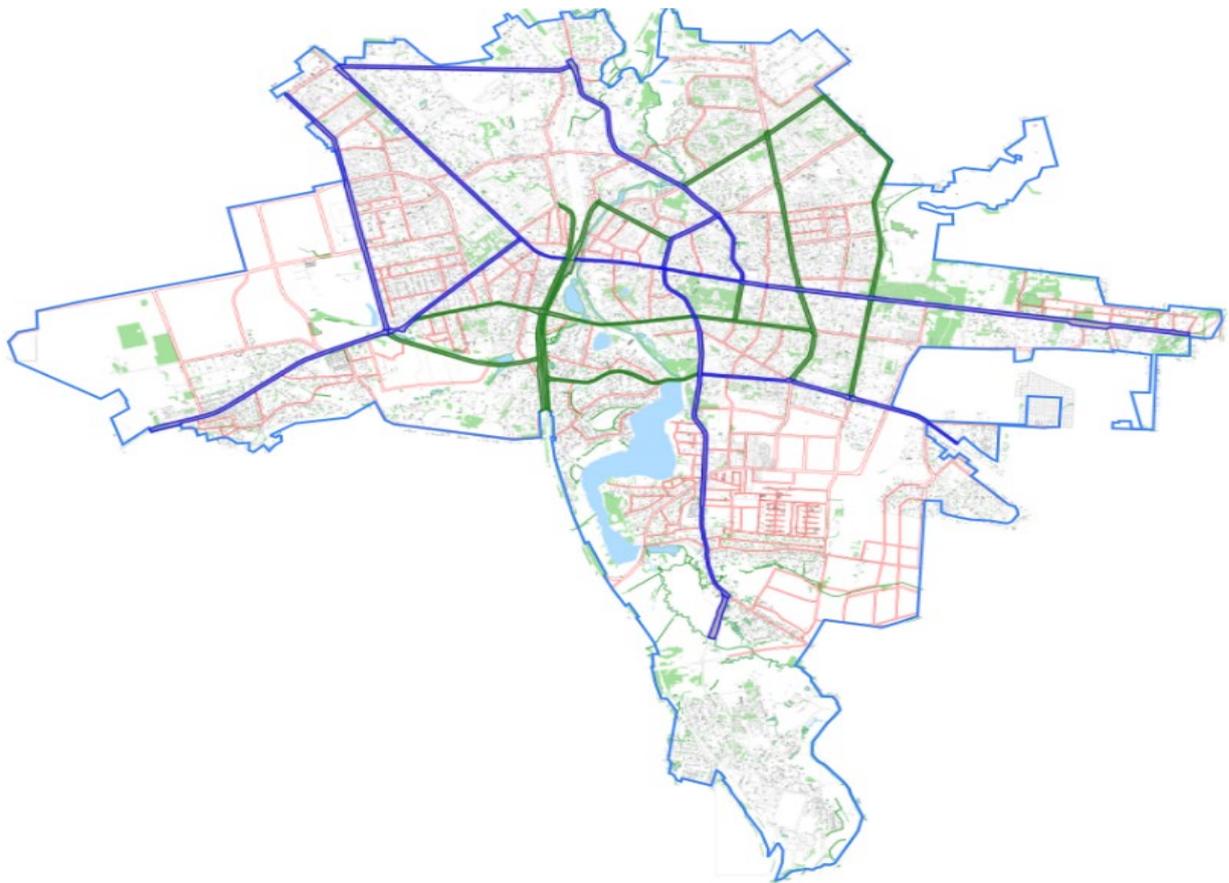


Figure 1 – Major Arterial Streets of Rivne and Their Connections to the City Centre

The problem is further exacerbated by the steady increase in the number of private vehicles, which has grown by one third over the past five years. At the same time, the level of satisfaction with public transport remains low, encouraging the use of personal cars even for short trips.

As of 2024, Rivne operates 12 trolleybus routes (71 units of rolling stock) and 20 bus

routes served by approximately 200 vehicles. Most buses run on diesel fuel, while the share of electric transport remains insignificant [5].

An analysis of the city's transport energy consumption (Table 1) shows that diesel fuel remains the dominant energy source for public and municipal transport.

Table 1. Energy Consumption of Transport in the City of Rivne, thousand liters per year

Year	Diesel Fuel	Gasoline	Liquefied Gas	Compressed Gas
2019	6207,7	182,6	84,6	224,9
2020	6222,2	166,2	84,8	199,3
2021	5719,0	148,5	76,3	168,9
2022	5402,1	97,9	69,7	117,4
2023	4966,0	102,7	107,4	94,1

Source: [1].

As shown in Table 1, diesel fuel consumption exceeds the combined consumption of other energy sources by 6–8 times. This makes the city's transport system

extremely energy-intensive and vulnerable to fuel price fluctuations. At the same time, recent years show a gradual decrease in energy consumption, which can be attributed

to a reduction in public transport volumes and partial renewal of the trolleybus fleet.

The predominance of diesel fuel in the energy consumption structure illustrates the

energy imbalance of the urban transport system (Fig. 2).

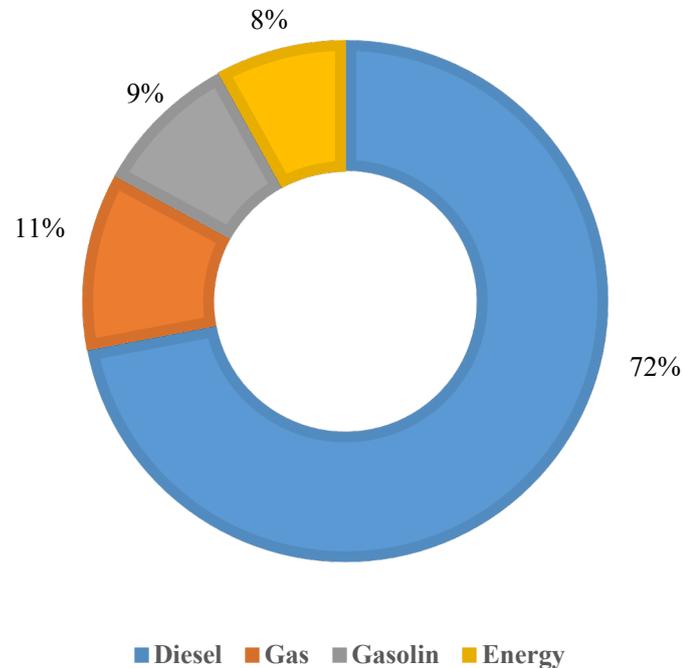


Figure 2 – Energy Consumption Structure of Transport in Rivne

Source: developed by the authors

Such a distribution indicates the dominance of fossil fuel sources and highlights the need for a systematic transport electrification policy.

At the same time, the city possesses a number of strengths that provide a foundation for developing an energy-efficient transport system: a compact urban structure,

the presence of electric transport, qualified specialists, and strategic documents on sustainable development. However, weaknesses—such as outdated trolleybuses, low comfort levels, and underdeveloped cycling infrastructure—remain significant barriers. A summarized assessment is presented in Table 2.

Table 2. SWOT Analysis of the Transport System of Rivne

Strengths	Weaknesses
Compact city structure	Aging trolleybus fleet
Developed road network	Dominance of diesel transport
Presence of electric transport	Underdeveloped cycling infrastructure
Qualified personnel	Low public satisfaction
Opportunities	
Development of electric transport and e-ticketing	Growth of private vehicle fleet
Support from international partners	Withdrawal of donor funding
"Green" transport corridors	Public resistance to reforms

Source: [1].

The analysis indicates that Rivne's transport system is on the verge of

transformation. The city has already implemented initial steps toward

digitalization: online services for tracking vehicle movement are operational, electronic display boards have been installed at stops, and a GPS system is in place. The next stage should involve the introduction of automated passenger accounting and an electronic ticketing system, which will ensure

transparency in transport financing and improve management efficiency.

To achieve climate neutrality in the transport system, it is necessary to implement an integrated energy efficiency concept (Fig. 3).

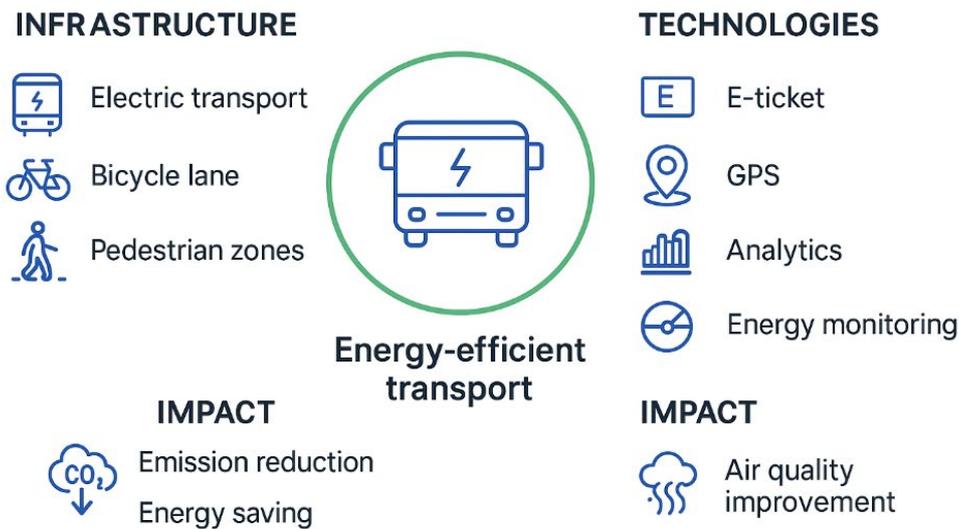


Figure 3 – Conceptual Model of a Balanced Urban Transport and Logistics System

The implementation of such a model enables the integration of engineering-technological, organizational, and social tools into a unified mobility management system.

The expected impact of these measures is illustrated by the potential reduction in

emissions (Fig. 4). These changes could achieve a 15% decrease from current emission levels even without reducing traffic intensity, solely through the transition to cleaner energy sources and optimization of traffic flows.

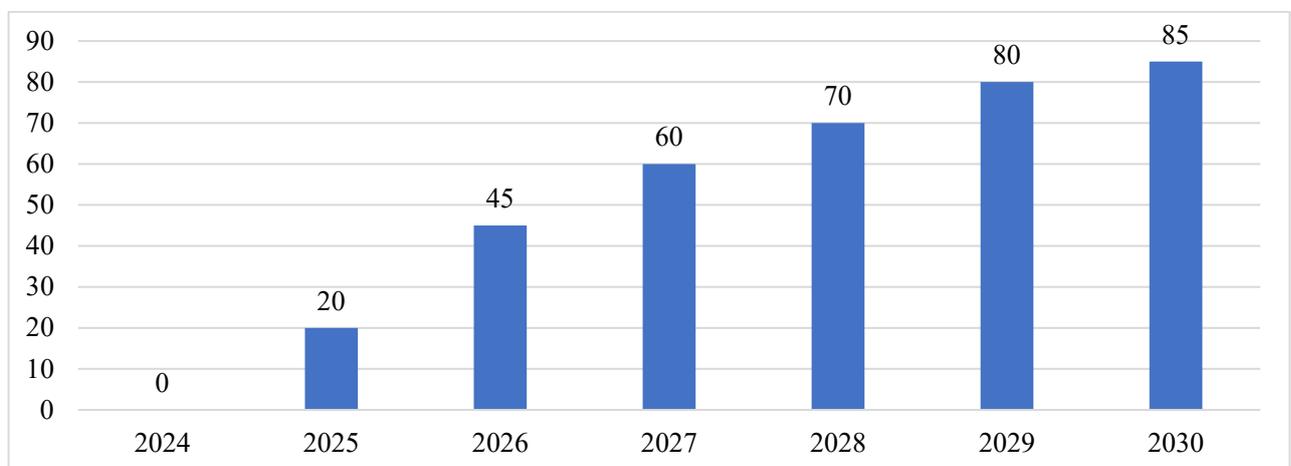


Figure 4 – Forecast of CO₂ Emission Reduction in Rivne with the Transition to Electric Transport (2024–2030)

Source: [1]

The results of the analysis of Rivne's transport system provide a basis for developing a generalized concept of energy efficiency for urban transport and logistics systems, which can serve as a model for medium-sized urban areas in Ukraine. The concept is based on the principles of sustainable development, energy rationality, innovation, and integrated mobility management.

The aim of the concept is to create a comprehensive urban transport

management system that minimizes energy consumption, reduces air pollution, improves the efficiency of logistics processes, and enhances the quality of life for the population.

Based on the conducted SWOT analysis and the identified characteristics of Rivne's urban transport network, a concept of an energy-efficient urban transport and logistics system has been developed, encompassing five interrelated implementation directions (Fig. 5).

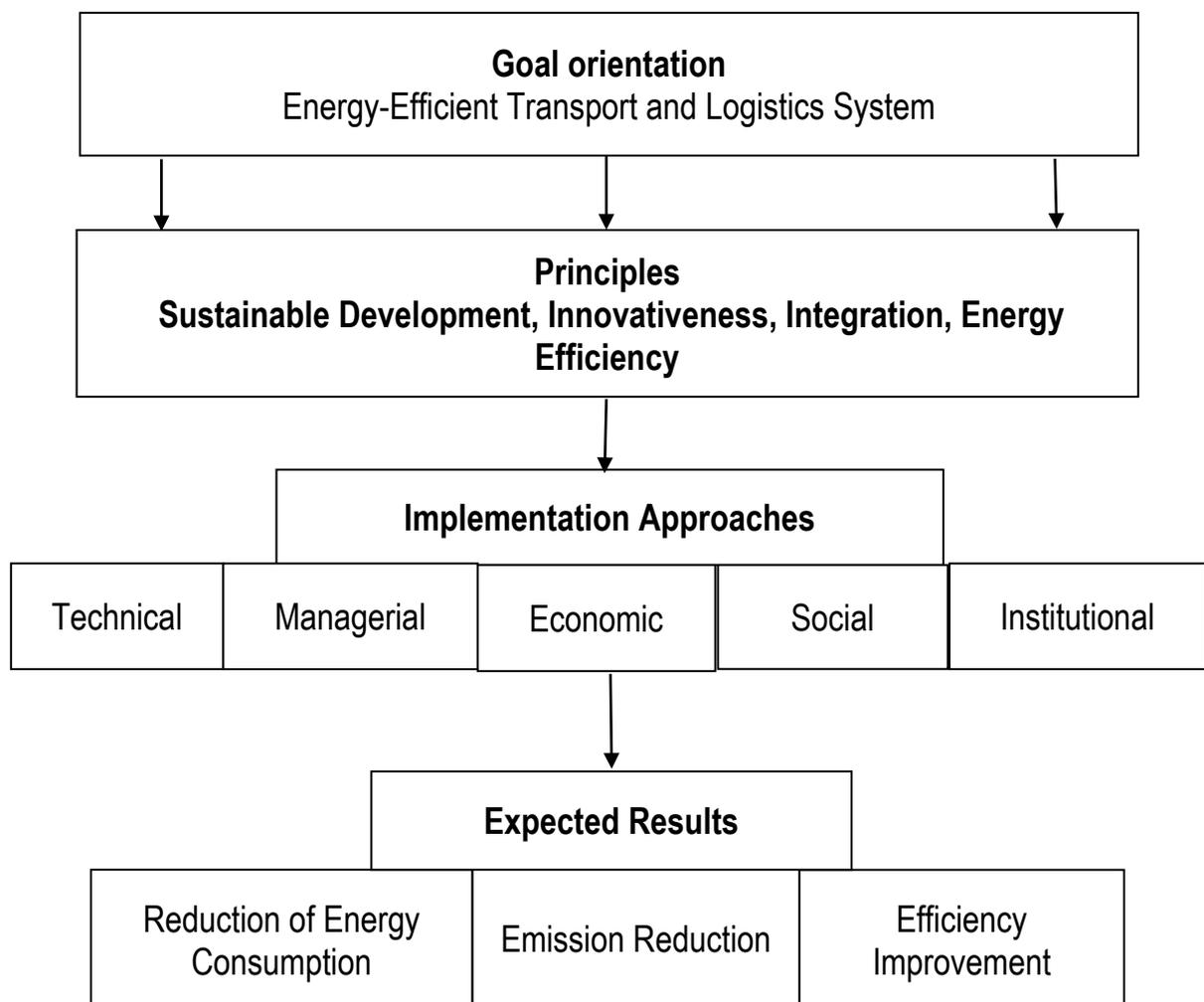


Figure 5 – Conceptual Structure of an Energy-Efficient Urban Transport and Logistics System
Source: [1]

1. Technical Implementation Direction. This includes the modernization of the public transport fleet, development of electric transport, creation of a network of charging stations, and upgrading lighting and traffic management systems based on energy-

saving technologies. The introduction of environmentally friendly transport (trolleybuses, electric buses, bicycles) will gradually reduce the use of diesel fuel, which currently accounts for over 80% of the city's transport energy consumption.

2. *Managerial Implementation Direction.*

This involves creating a digital urban mobility management platform that integrates GPS navigation, electronic ticketing, automated passenger accounting, and energy consumption analytics. It will enhance the efficiency of the route network and reduce unproductive trips, aligning with the digitalization measures already implemented in the city (GPS tracking and electronic display boards at stops).

3. *Economic Implementation Direction.*

This direction provides mechanisms to incentivize energy-efficient transport, including preferential loans for transport operators to renew their fleets, attracting grant funding, and partnership programs with international donors. This approach is designed to mitigate the threat of reduced donor funding identified in the SWOT analysis.

4. *Social Implementation Direction.* This focuses on changing residents' travel behavior by promoting public and bicycle transport, improving passenger comfort, and developing infrastructure for pedestrians and micromobility. Shaping a transport culture is a key factor in energy efficiency, as consumer habits often determine the system's overall energy use.

5. *Institutional Implementation Direction.*

This is based on cooperation among local authorities, businesses, the public, and educational institutions in implementing a unified transport energy efficiency policy. The concept foresees the creation of a municipal coordination center for mobility, which will monitor energy efficiency indicators and develop plans for transitioning to climate-neutral transport.

The implementation of the concept will facilitate the city's transition to a balanced logistics model, integrating technical, economic, and social solutions. Its foundation lies in the integration of digital technologies with sustainable urban planning practices.

Conclusions. The proposed concept of energy efficiency for urban transport and

logistics systems can be adapted to different levels of governance:

1. Local government – as a strategic basis for developing programs on transport energy independence and sustainable urban development;

2. Business sector – to improve the energy efficiency of logistics operations, optimize transport, and develop "green" branding for enterprises;

3. Educational environment – for the implementation of academic courses on urban logistics, e-mobility, and energy resource management;

4. Public initiatives – as a tool to foster a culture of rational energy consumption and environmentally responsible mobility.

The developed concept serves as a universal model applicable to cities of various scales, from medium-sized urban areas to large metropolitan regions. It is based on the integration of technical, organizational, economic, and social implementation directions, which ensure reduced energy consumption, lower pollutant emissions, and increased efficiency of urban logistics.

Thus, the concept of energy efficiency in urban transport and logistics systems is a key element of sustainable urban development strategy and the transition toward climate-neutral mobility.

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STRATEGIC MANAGEMENT OF SUSTAINABLE DEVELOPMENT OF TRANSPORT INFRASTRUCTURE AS A COMPONENT OF THE ECONOMIC SECURITY OF UKRAINE

Viktor Koval, Larysa Soroka, Tetiana Metil, Iryna Honcharova, Oleh Kior, Serhii Khakhlov. *«Strategic management of sustainable development of transport infrastructure as a component of the economic security of Ukraine». Infrastructure provision is a key factor in the efficiency of the transport service system for consumers. Therefore, in the process of implementing strategic management for the sustainable development of transport infrastructure, scientific issues arise that require a comprehensive solution. This study is devoted to determining priorities in the process of forming the concept of strategic management of sustainable development of transport infrastructure of Ukraine in general, and maritime transport infrastructure in particular, since it is precisely on the ability of maritime transport to ensure export-import operations that the economic security of Ukraine, and in some cases the global system of economic security, depends. The article proposes a scheme for interaction among various participants in the strategic management of sustainable maritime transport infrastructure development. The system of organizational and economic measures to enhance the efficiency of maritime transport infrastructure is also analyzed. The level of provision of the system of various transportation with maritime transport infrastructure depends on Ukraine's economic security and its image as a reliable partner in the process of implementing international agreements, which are the basic motives for the formation of sustainable infrastructure development.*

Keywords: transport infrastructure, maritime transport infrastructure, strategic management, sustainable development, economic security, food security, fixed assets, transport services, grain exports, water transport, maritime transport.

Віктор Коваль, Лариса Сорока, Тетяна Метіль, Ірина Гончарова, Олег Кіор, Сергій Хахльов. *«Стратегічне управління сталим розвитком транспортної інфраструктури як складова економічної безпеки України». Інфраструктурне забезпечення є одним з головних чинників ефективності системи транспортного обслуговування споживачів, тому в процесі здійснення стратегічного управління сталим розвитком транспортної інфраструктури постають наукові питання, що потребують комплексного вирішення. Ця стаття присвячена визначенню пріоритетів у процесі формування концепції стратегічного управління сталим розвитком транспортної інфраструктури України взагалі, та морської транспортної інфраструктури в частці, оскільки саме від спроможності морського транспорту забезпечувати експортно-імпорتنі операції залежить економічна безпека України, та у деяких випадках загальносвітова система економічної безпеки. У статті запропоновано схему взаємодії різних учасників стратегічного управління сталим розвитком морської транспортної інфраструктури. Також проаналізовано систему організаційно-економічних заходів щодо підвищення ефективності*

використання морської транспортної інфраструктури. Від рівня забезпеченості морською транспортною інфраструктурою системи різноманітних перевезень залежить економічна безпека України, імідж держави як надійного партнера в процесі виконання міжнародних угод, що є базисними мотивами до формування сталого розвитку інфраструктури взагалі.

Ключові слова: транспортна інфраструктура, морська транспортна інфраструктура, стратегічне управління, сталий розвиток, економічна безпека, продовольча безпека, необоротні активи, транспортні послуги, зерновий експорт, водні види транспорту, морський транспорт

Introduction. The formation of the country's economic security is based on a strategic combination of various factors and components, including both physical and virtual elements. However, it considers the formation of various components of economic security. A system of indicators is created, most of which depend on the quality of transport services, since transport service operations accompany any physical movement of goods, and in some cases, services. That is, the level of development of transport infrastructure has a direct impact on the formation and degree of ensuring the country's economic security.

In Ukraine, the transport infrastructure is quite developed, but in conditions of military and geopolitical threats, it requires significant use of strategic development, since the requirements for its condition and quality of transport services are constantly changing, which creates the need for a fundamentally new approach to strategic management of transport infrastructure development.

The growth of demand for multimodal transportation, the presence of special requirements for the conditions of transportation and storage of goods, bringing information support for freight and passenger transportation in line with consumer requirements leads to the need to improve all components of the transport infrastructure, both directly on transport. and in the field of providing related services [1].

The creation of new approaches to the formation of the offer of transport services on the market of these services forms updated algorithms of actions in the context of determining consumer characteristics, forming a system of requirements, and

creating infrastructure components in accordance with consumer expectations.

Ensuring high-quality strategic management in the field of improving transport infrastructure has specifics for different types of transport. For land transport, the basis is measures to improve highways, since the level of consumer satisfaction in transport services depends on the degree of coverage of the transport network. Of particular importance for the development of transport infrastructure as a set of material and technical means is maritime transport infrastructure, since the level of its development depends on the country's export capacity [2].

The purpose of writing the article is to determine the priority areas for the development of maritime transport infrastructure as an integral part of the overall infrastructure system.

In the process of achieving the set goal, the current state of infrastructure provision for export-import operations in the seaports of Ukraine was determined, and what measures are envisaged by the National Transport Strategy of Ukraine for the period until 2030 to improve the infrastructure provision for export-import operations in the seaports of Ukraine were considered.

Literature review. Many scientists study the impact of transport infrastructure development conditions on the economic security of countries with different levels of involvement in the international transport system, especially in the implementation of agreements aimed at forming a global food security system. However, previously conducted studies do not fully reproduce the theoretical and methodological provisions,

the diversification of which is aimed at improving the system of strategic management of transport infrastructure development.

If we consider global trends in the development of transport and logistics services, then, as M. Kyrpyk (2021) notes, there are threats of significant imbalances in the development of transport services in different parts of the world, primarily due to different access to different types of energy sources [3]. V. Yevtushenko and others (2023) note that for Ukraine in the process of developing global transport and logistics routes there is a large transit potential, which is reflected in the prospects for the development of the logistics services market in Ukraine [4].

However, according to O. Kalchenko and A. Belorus (2021), there are a number of problems in the development of the transport sector in Ukraine, in particular infrastructure problems, which arise both due to the obsolescence of material assets and the lack of high-quality channels for the circulation of significant amounts of information, which are necessary for high-quality information support when making strategic decisions on the development of transport infrastructure, especially as a component of economic security [5]. V. O. Kopylova and Y. V. Pichugina (2024) provided interesting proposals for the use of cooperation between different types of transport, which should contribute to the qualitative improvement of transport and logistics systems operating in Ukraine, including taking into account the characteristics of maritime transport [6].

To improve the quality of use of Ukraine's transit potential, T. Bernevek and V. Prokhorov (2024) propose to expand the degree of integration of Ukraine's maritime transport system into global transport networks, however, the authors do not focus on the components of strategic management of transport infrastructure development as a whole, which does not fully reflect the possibilities of using maritime transport infrastructure in the process of improving Ukraine's economic security [7]. D.M.

Zagirnyak et al. (2021) focus on ways to ensure the competitiveness of transport services, but do not take into account some features of strategic management of transport infrastructure development [8]. V. Stepanenko and Y. Shtyk (2022) when studying the areas of increasing the competitiveness of Ukraine's maritime transport infrastructure also do not take into account the features of strategic management of the complex development of various components of transport infrastructure, as a result of which Ukraine's economic security may be limited [9].

Considering various components of building strategic management models in the process of forming a sustainable development system by various components of transport infrastructure, different researchers offer different concepts of this management. V. Koval et al. (2023) offer ways to manage an integrated model of innovations in maritime transport [10].

M. Penev et al. (2024) consider multimodality as an integral part of the modern system of transport provision for consumers, therefore emphasize the need for timely adaptation of infrastructure components to the provision of services in the process of multimodal transportation [11]. Y. Klyus et al. (2023) propose to apply various analytical approaches to the choice of directions of strategic management of innovative development of enterprises in the region, including transport, which makes it possible to form a unified approach to measures aimed at increasing the economic security of Ukraine [12]. These separate components need to be generalized in order to create effective recommendations for improving the system of strategic management of transport infrastructure development as a component of Ukraine's economic security, since there are certain threats that are reflected by L. Zaborsky and D. Shaposhnykov (2024) in the process of studying the security of transport provision of Ukrainian grain exports [13].

In addition to purely economic security issues, balanced strategic decisions are needed in the process of managing the development of transport infrastructure on an ecological basis, since, as noted by V. Koval et al. (2024), there are a number of problems with the development of environmentally dangerous and economically feasible solutions in the field of transport infrastructure development on the basis of the digital economy [14]. V. Koval et al. (2025) note that there are certain threats when imbalances arise in the development of various components of transport infrastructure [15].

Therefore, the process of optimizing the conditions for making balanced decisions in the course of implementing strategic management of transport infrastructure development is one of the important components of Ukraine's economic security. However, since the processes of forming the components of strategic management of sustainable development of maritime transport infrastructure are constantly improving, they require additional study.

Presentation of the main material.

Strategic management of the improvement of various infrastructure components is based on the principles of systematicity, complexity, priority, application of innovative solutions, sustainable development, partnership and coordination, economic feasibility, flexibility and adaptability, and territorial balance. Infrastructure improvement should be carried out in a comprehensive manner, which is of particular importance for the economic security of Ukraine. Infrastructure development measures should cover all levels, such as technical, organizational, institutional, and financial. The effectiveness of strategic management of sustainable development of maritime transport infrastructure is significantly affected by the formation of interaction between various participants in the processes of supporting measures to modernize infrastructure components. Figure 1 shows a general scheme of interaction between participants in the strategic management of sustainable development of maritime transport infrastructure.



Figure 1 – Scheme of interaction of participants in the strategic management of sustainable development of maritime transport infrastructure.

Source: summarized by the authors

Transport provision is of particular importance for the formation of a balanced system of general infrastructure renewal. Therefore, one of the priority tasks in the process of comprehensive infrastructure renewal is the renewal of transport infrastructure and modernization of the existing fleet of vehicles, which will allow for a systematic approach to strategic planning of the modernization of other components of economic infrastructure [16].

Ukraine has certain problems with comprehensive infrastructure renewal, which is characterized by significant volumes of

assets, the original cost of which is fully depreciated, namely, in 2019 this cost amounted to 1138.6 billion UAH., in 2020 - 1376.8 billion UAH., in 2021 - 879.4 billion UAH. Unfortunately, similar studies have not been published by the State Statistics Service of Ukraine for the periods before 2019 and after 2021. If we consider the original cost of non-current assets for which depreciation has been fully accrued, then for the period from 2019 to 2021, the average indicators of the composition of the original cost are shown in Figure 2.

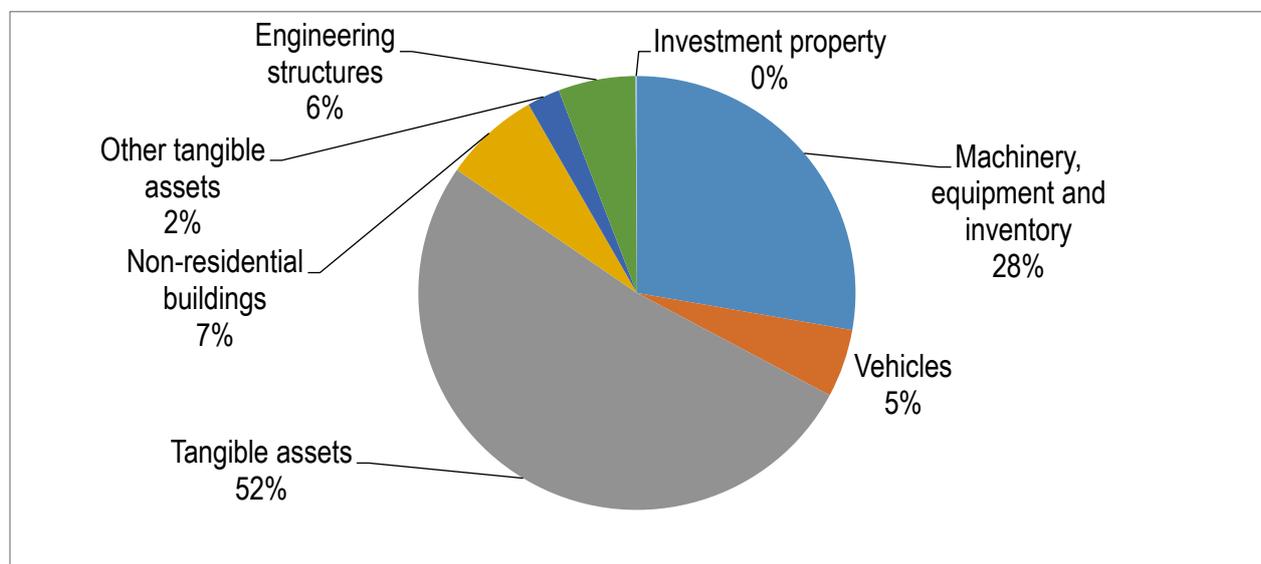


Figure 2. Structure of fully depreciated non-current assets, average figures for 2019-2021

Source: [17]

Significant volumes of obsolete non-current assets that do not meet the conditions for effectively ensuring the economic security of Ukraine create challenges for urgent solutions to infrastructure issues. According to the World Bank, in 2021, infrastructure projects worth 1.4 billion euros were implemented in Ukraine in the transport sector, with 7% of investments in innovative projects coming from the state budget, 8% from local budgets and loans, 3% from foreign investors, and 82% from private investors, which demonstrates the great interest of private business in improving transport infrastructure. However, during the full-scale

invasion, the transport infrastructure suffered significant damage. Most of the Ukrainian ports were affected by the strikes and were partially or indefinitely withdrawn from full round-the-clock support in a functional state. The main ports remain the ports of Greater Odessa, namely Odesa, Pivdennyi and Chornomorsk, which operate under increased risk and with damaged infrastructure. The total cost estimate for the reconstruction of critical port infrastructure is about 500 million euros according to estimates by independent experts. The cost of a complete modernization of the port infrastructure has not been determined, since information on

the strategic needs of the ports is not systematized. At the same time, significant investment projects for the entire port infrastructure are being implemented in the Black Sea region, especially in the Romanian port of Constanta, which diverts part of the cargo flow that was previously transported through the ports of Ukraine. Due to partial damage to berths and port cranes, a shortage of warehouses and capacities, weak logistical support, and increased operational risks, Ukraine is losing confidence in its international positions as a reliable transport partner, so there is an urgent need to improve transport infrastructure.

To streamline measures to update transport infrastructure and to determine the main measures for strategic management of transport infrastructure development as a component of Ukraine's economic security, in 2024 the Cabinet of Ministers of Ukraine adopted the National Transport Strategy of Ukraine until 2030. The main measures of the

Strategy are aimed at bringing the level of infrastructure support closer to European standards. General measures aimed at modernizing transport infrastructure for the high-quality functioning of water transport, including sea and river, consist of creating infrastructure capabilities for cargo handling, security, and integration with other modes of transport. It is also proposed to increase the institutional capacity of port management [18].

Despite the obsolescence of the infrastructure support of the transport system of Ukraine, in order to streamline the measures that will be implemented within the framework of strategic management of the development of transport infrastructure as a component of the economic security of Ukraine, the following organizational and economic measures aimed at increasing the efficiency of the use of maritime transport infrastructure are currently relevant (Table 1).

Table 1. Main organizational and economic measures to increase the efficiency of the use of maritime transport infrastructure

Direction	Main activities
Improving port management	Implementation of corporate governance principles
	Optimization of organizational structure
	Creation of a single digital port management center
	Implementation of the "single window" system
Economic and investment mechanisms	Development of public-private partnership models
	Attracting private investors
	Differentiation of tariffs and port dues
	Optimization of port capacity utilization
Technical and innovative modernization	Creation of free economic zones
	Automation of port processes
	Intelligent cargo flow management systems
	Reconstruction of berthing facilities
	Development of intermodal transport hubs
Logistics and marketing policy	Implementation of "green port" technologies
	Optimization of logistics routes
	Creating marketing strategies for ports
	Development of transport and logistics clusters
Personnel and institutional measures	Increasing the share of high-yield cargo
	Staff training
	Implementation of a staff motivation system
	Development of scientific and educational centers
	Harmonization of the legal framework with EU requirements

International cooperation and integration	Participation in international transport corridors
	Involvement of international financial institutions

Source: summarized by the authors

The listed organizational and economic measures will make it possible to take into account modern global trends in strategic management of maritime transport infrastructure development at the stage of forming the prerequisites for creating a high-quality environment for the development of transport infrastructure as a component of Ukraine's economic security.

Conclusions. Creating conditions for high-quality and timely strategic management of sustainable development of transport infrastructure is one of the main factors of Ukraine's economic security, since the quality of ensuring many processes in the state's vital activity system depends on the flexibility and adaptability of this management. This multi-component and multi-vector process has a large number of stakeholders, each of which ensures the effectiveness of the implementation of management decisions at its own level.

However, the overall effectiveness of sustainable development of transport infrastructure depends on the formation of the strategic management system itself, which should encourage those responsible for making management decisions to pay increased attention to each of the infrastructure elements.

A special role in the formation of domestic Ukrainian and global economic security systems is played by components of maritime transport infrastructure, which creates the necessary conditions for managing components of maritime transport infrastructure, since the quality of sustainable development of both individual elements and the industry as a whole depends on this. High-quality strategic management of sustainable development of transport infrastructure allows for the formation of an effective infrastructure environment, which is a necessary condition for ensuring economic security.

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DEVELOPMENT OF ROAD ELECTRIC TRANSPORT AS A KEY ELEMENT OF GREEN LOGISTICS, ITS IMPORTANCE IN THE CONTEXT OF ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

Vladyslav Marchenko. «*Development of road electric transport as a key element of green logistics, its importance in the context of achieving sustainable development goals*». In this work, a complex analysis of the development of road electric vehicles as a key element of green logistics was carried out, and its significance in the context of achieving key sustainable development goals was described. Based on different authoritative sources, the main years and events in the history of electric transport development were indicated, with the aim of demonstrating how this industry evolved from the first experiments to the formation of a full-fledged segment of the global market. In the article, it was explained in detail what modern electric transport represents, and its key technological foundations were described. Thanks to the conducted analysis, the key advantages of road electric transport were summarized. An equally important step in the work was explaining the global status of the road electric transport market, revealing the share of electric transport in the transport sector, and listing the key players of this market. Also, in this paper, the key challenges that stand on the way of the development of road electric transport were systematized. Based on the conducted research, a conclusion was made regarding the need to continue comprehensive study and development of this sphere.

Keywords: development, ecology, sustainability, technologies, efficiency, prospects, electricity, transport, logistics, management

Владислав Марченко. «*Розвиток дорожнього електричного транспорту, як ключового елементу зеленої логістики, його важливість у контексті досягнення цілей сталого розвитку*». У роботі здійснено комплексний аналіз розвитку дорожніх електромобілів як ключового елементу зеленої логістики та описано його значення в контексті досягнення ключових цілей сталого розвитку. На основі різних авторитетних джерел було вказано основні роки та події в історії розвитку електротранспорту, з ціллю демонстрації, як ця галузь еволюціонувала від перших експериментів і аж до формування повноцінного сегмента глобального ринку. В статті було детально пояснено, що ж собою представляє сучасний електричний транспорт, описано його ключові технологічні основи. Завдяки проведеному аналізу було підсумовано ключові переваги дорожнього електротранспорту. Не менш важливим кроком в роботі стало пояснення глобального стану ринку дорожнього електротранспорту, розкриття частки електротранспорту у

транспортному секторі та перерахування ключових гравців даного ринку. Також у роботі було систематизовано ключові виклики, що стоять на шляху розвитку дорожнього електротранспорту. На основі здійсненого дослідження було сформульовано висновок щодо необхідності продовження всестороннього вивчення та розвитку даної сфери.

Ключові слова: розвиток, екологія, сталість, технології, ефективність, перспективи, електрика, транспорт, логістика, менеджмент

Introduction. Over the past centuries, humanity has come an incredible way in all spheres of life. However, despite all the large-scale achievements and accomplishments, it is necessary to remember about the serious global challenges that accompany this process. Ecological, economic, and social problems have continued their transformation and have become even more acute and relevant than ever before. Environmental pollution, climate change, the gradual depletion of natural resources, energy crises, the destruction of natural ecosystems, and the loss of biodiversity are just the beginning of a wide list of serious difficulties that humanity faces at present. With the passage of time, the negative anthropogenic impact on the planet has continued to grow. Rapid industrialization, inefficient use of resources, and irrational energy consumption have led to a situation where natural systems have begun to degrade, simply unable to recover. Today, the global economy's dependence on fossil fuels remains extremely high. It is therefore not surprising that attitudes toward the use of oil, coal, and natural gas are slowly changing. In our time, their use is not considered anymore as an innovative solution, but rather as an outdated idea that should step by step become a thing of the past. The need of finding new harmonious practices of global development has prompted humanity to create and massively apply the concept of sustainable development, which aims to balance environmental, economic, and social factors. One of the most important areas for its implementation has become logistics. It is inextricably linked to the transport sector, which is currently one of the key sources of environmental pollution and energy

consumption, and therefore the question of its comprehensive green modernization was not long in coming. The idea of green logistics emerged as a decisive response to society's demand to find more modern approaches to development. As a concept, it was aimed at minimizing the negative ecological impact of logistics on the environment through the use of green technologies, ecological practices, and new standards. By balancing ecological, economic, and social aspects according to a sustainable principle, it allows us to identify the most effective strategies for reducing the negative impact of logistics on the environment and bring them to life. In our time, one of the most important elements of green logistics is undoubtedly the use of electric transport. The idea of developing this direction has already had the opportunity to demonstrate its effectiveness and high prospects in practice many times. By using all possible electric scooters, electric cars, electric buses, and heavy-duty electric vehicles, we are not only actively countering climate change, but also significantly reducing the global economy's dependence on traditional fossil fuels. The active development of electric transport can become the driving force behind a new ecological, economic, and energy revolution. Since it has truly enormous undiscovered potential, it is important today to continue researching this direction in the scientific community and to look for modern ways to support and develop it.

The purpose of the article is to explain why road electric transport is a key element of green logistics, indicate its importance in the context of achieving sustainable development goals. This article will reveal the role of electric transport for the modern world, key periods in the historical

development of electric vehicles, the basic technological foundations of electric transport, main advantages of road electric vehicles, the current situation on the global road electric transport market and barriers that stand on the way of its development.

Presentation of the main results. Humanity has spent a lot of time and effort searching for an effective response to the above-mentioned ecological, economic, and social challenges. The concept of sustainable

development has become one of the most efficient and promising ideas, the realization of which would enable society to counter these global threats. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. It is based on an optimal balance between three pillars: environmental resilience, economic growth, and social justice, as clearly illustrated in Fig. 1.



Figure 1 – The 3 pillars of sustainability

Source: Developed by Vladyslav Marchenko

At present, many scientists see the concept of sustainable development as a new ideology for the future. It has gained such unprecedented popularity since it aims to create a system where economic, ecological, and social aspects are harmonized. And that's why the gradual introduction of the above-mentioned concept into the logistics sector was only a matter of time.

For decades, experts have been looking for ways to make the transport industry more eco-friendly and sustainable. The reality where it is one of the biggest sources of

environmental pollution and energy consumption didn't suit modern society, forcing it to find more sustainable approaches to its development. Green logistics has become a decisive response to this problem. It aimed to seriously reduce the negative ecological impact of this industry on the environment.

The idea of implementing sustainable development principles in the field of transport and supply relied on the use of modern ecological practices, green technologies, and new standards. In order to

minimize the negative anthropogenic impact on the environment, it was decided to place greater emphasis on optimizing logistics systems, reducing greenhouse gas emissions, and increasing the efficiency of operational processes through more productive use of energy resources, the application of eco-friendly transport, and the establishment of a circular economy. All these decisions are extremely important for preserving our planet for future generations.

Green logistics is known worldwide for its use of unconventional technologies, methods, and standards. It has clearly indicated that the success of countering modern global challenges directly depends on how creative, innovative, and comprehensive the tools used by humanity are. A modern example of such an instrument is the development of eco-friendly transport systems. Twenty years ago, the widespread use of electric transport was considered as a science fiction, but today this direction is our reality, an important element of green logistics, and a necessary means for achieving sustainable development.

Electric road transport is one of the major keys to the efficient transformation not only of the logistics industry, but also of cities and entire regions. Electric transport encompasses all modes of transportation powered by electric engines, including electric cars, e-bikes, e-scooters, and even electric buses and trucks [2]. Its role for the modern world is of unprecedented importance. Unlike transport vehicles that run on fossil fuels and pollute the atmosphere, it is an eco-friendly tool that can replace them in the long term perspective. Due to its environmental friendliness, economic and energy efficiency, it has become one of the key elements essential for achieving sustainable development goals. Research,

development, and further improvement in this direction are important steps towards ensuring a sustainable future and overcoming the existing global challenges that humanity faces.

Based on the above mentioned data, it was decided to explain in more detail in this article the development of road electric transport as a key element of green logistics, its importance in the context of achieving sustainable development goals. The first element that needs to be more fully disclosed after this initial theoretical basis is the significance of road electric transport in the task of achieving sustainable development goals. The United Nations has identified 17 sustainable development goals (SDGs) that are designed to ensure a balance between modern society and nature, as clearly demonstrated in Fig. 2.

The development of the sphere of road electric transport allows to implement various aspects of this concept, ranging from promoting economic growth and improving the level of the population's well-being to reducing the negative impact on the environment.

The factor of public well-being and health cannot be underestimated. They represent important elements that guarantee its effectiveness and coherence. And electric transport plays a key role in achieving SDG №3, «Good health and well-being». Traditional road transport modes that run on fossil fuels have a serious negative impact on human health. This is especially well understood by citizens living in densely populated urban areas with a large number of such vehicles, as high noise levels and air pollution increase the risk of diseases related to the respiratory and cardiovascular systems.



Figure 2 – 17 Sustainable Development Goals

Source: Developed by Vladyslav Marchenko

Equally important are SDG №8, «Decent work and economic growth», and SDG №9, «Industry, innovation, and infrastructure». The use of electric road transport effectively contributes to the achievement of each of these tasks. The development of the sphere of electric transport not only guarantees the creation of a huge number of new jobs now, but also aims to ensure tangible economic growth for companies in the long term. The creation of new technological innovations in this area and the development of already existing directions has a positive impact on increasing the competitiveness of countries on the international arena.

It is also worth noting SDG №11, «Sustainable cities and communities», as electric road transport is a key element in this system, which guarantees the creation of high-quality, safe, quiet, comfortable, and clean settlements. The development of this direction allows to significantly increase the mobility of the population and comfort for all its residents. Citizens particularly appreciate

the fact that the introduction of electric transport contributes to a reduction in noise levels and carbon dioxide emissions into the atmosphere.

It is impossible not to mention SDG №12, «Responsible consumption and production». At present, the goal of preserving the planet's natural resources is one of the highest priorities. Electric transport is a solution that guarantees a more sustainable future for humanity. It not only provides an opportunity to reduce dependence on non-renewable fuels, but also implements renewable energy sources in its activities.

The task of minimizing greenhouse gas emissions also requires attention. That is why it is important to highlight the key role of electric transport in achieving SDG №13, «Climate action». Today, due to large carbon dioxide emissions into the atmosphere, traditional fossil fuel-powered transport is considered one of the most serious sources of environmental pollution. Scientists have concluded that the decision to develop the

transport sector in the direction of electric transport can counteract climate change and slow down the rate of global warming.

This list can be extended further, but even the examples mentioned above are sufficient to emphasize that modern electric transport is a truly powerful strategic solution that allows to effectively achieve many sustainable development goals. Its application corresponds to the new principle of balancing ecological, economic, and social factors of

development, which is so important in our time.

The second important task that is necessary for a complete disclosure of the chosen topic is a detailed study of the history of the development of road electric transport, its key years, scientists, inventors, events, tendencies and achievements. Key years and events in its history are presented in Table 1.

Table 1. Key years and events in the history of electric transport development

Date	Events
1828	Anyos István Jedlik was a Hungarian engineer, physicist and Benedictine priest. In 1828, he created a primitive electric motor and used it to power a small model vehicle.
1834	Thomas Davenport was blacksmith and inventor from Vermont. In 1834, he developed a battery-powered electric motor. It was used to operate a small-model car on a short section of track. This action paved the way for the further electrification of streetcars.
1832 - 1839	Robert Anderson was a Scottish inventor. Between 1832 and 1839, he designed a carriage powered by electricity.
1859	Gaston Planté was a French physicist. In 1859, he invented a lead-acid battery. This type battery was the first rechargeable battery. This was an important step in the direction of practical energy storage.
1881	Gustave Trouvé was a French electrical engineer and inventor. In 1881, he debuted with an electric tricycle (Trouvé Tricycle) at the International Exhibition of Electricity in Paris.
1888	Andreas Flocken was a German entrepreneur and inventor. In 1888, he created one of the first successful electric vehicles, known as the «Flocken Elektrowagen».
1897	Walter Charles Bersey was a British electrical engineer. In 1897, he introduced the first electric taxis, dubbed «hummingbirds» because of their relatively quiet buzz.
1899	Camille Jenatzy was a Belgian inventor and race car driver. On April 29, 1899, La Jamais Contente, designed and driven by him, became the first electric car to exceed a speed of 100 km/h.
1959	In 1959, the Henney Kilowatt electric car debuted on the US market. Many people call it the first «modern» American electric car.
1966	In 1966, the US Congress introduced the first bills recommending the use of electric transport as a means of reducing air pollution.
1973	The 1973 oil embargo led to a significant increase in interest in electric vehicles. The number of promising new researches in this area has grown significantly.
1996	General Motors started delivery of the EV1. At that time, this electric vehicle was a real technical achievement.
2010	In 2010, Nissan released the world's first mass-market electric vehicle (Nissan Leaf). This decision marked the beginning of the world's transition to zero emissions from motor vehicles and carbon neutrality.
2012	In 2012, Tesla introduced the Model S sedan. It changed the electric transport market and became one of the best-selling electric vehicles in 2015 and 2016.
2013 - 2018	This period was marked by the popularization of lithium-ion batteries and was memorable for a significant drop in prices for them.

Date	Events
2022	In 2022, the US president signed Inflation Reduction Act. This decision was one of the most important steps taken by Congress in the field of clean energy and climate change in the history of this country.
2023	According to the IEA, in 2023, the global electric car sales volume reached almost 14 million. This is 35% more than in 2022.

Source: created by the author based on [3-19].

The conducted analysis of the history of electric transport has shown that it has passed a very complex and difficult route, starting from the emergence of the idea itself and the very first experiments, up to the current high-tech and very promising innovations. Today, this direction has already become a real global market, but an analysis of the recent history of electric transport has shown that its position has not always been stable and peaceful, but quite the opposite. Its development has had quite distinct wave-like periods. Growing interest in electric transport and rapid progress were followed by a decline in this trend and doubts about its feasibility. For many decades, the traditional internal combustion engine dominated all other solutions, and only a combination of serious global challenges, such as climate change, environmental pollution, depletion of natural resources, and energy crises, forced society to continue searching for other possible alternatives. The critical nature of the existing threats and the corresponding development of the lithium-ion batteries sector have become the preconditions for today's electric transport transformation. The current century has been marked by the emergence of effective innovations, the appearance of new electric transport manufacturers, and even its full-fledged competition with traditional cars. Now, the sphere of electric transport is confidently gaining momentum and qualitatively integrating into the global logistics network.

No less important task for revealing the chosen topic of the article is a brief explanation of what modern electric transport actually is and its key technological foundations. Today, its main components include accumulators, electric motors, appropriate software, and charging

infrastructure. This set of elements ensures its environmental friendliness, high performance, quality, and reliability.

The first element that fundamentally distinguishes electric transport from traditional transport is the accumulator. The source of energy for electric transport is not fossil fuels, but powerful accumulator batteries. The key technical characteristics of electric transport, such as speed, acceleration, transportation range, etc., mainly depend on how modern and productive the battery is. Currently, lithium-ion batteries are the most popular type of accumulator. They have become so widespread because of their long life cycle, high capacity, and good charging speed. But it should be noted right away that technologies in this field are not standing still, and many scientists and experts are already discussing the prospects of using solid-state batteries. Compared to lithium-ion accumulators, these batteries are even more reliable, have a longer service life, charge quickly, and offer even greater capacity with the same weight, which is a very serious argument in their favor.

The second element of electric transport is the electric motor. It is an integral center that connects all the systems of the vehicle. Compared to traditional transport, it is notable for its simplicity, compactness, high energy efficiency, and uncomplicated design. Electric motors perform fast torque, which increases the maneuverability and dynamics of transport. The most common types of AC motors include permanent magnet motors and asynchronous motors. They are respected for their wide torque range and high efficiency. In comparison with traditional transport, it is worth mentioning such an advantage as the absence of complex mechanisms, as this undoubtedly simplifies

the service maintenance of electric transport and minimizes the risk of the occurrence of different breakdowns.

The third element of electric transport on which manufacturers are placing special emphasis in our time is the appropriate software. Practically all modern models are equipped with it to a certain extent. Different software modules work nonstop in order to guarantee the optimal operation of all transport systems, ensure the correct functioning of all elements during the driving process, and provide high-quality feedback to the driver. Battery management, engine management, energy recovery, heat management, car charging, GPS, and autopilot are all absolutely possible functions nowadays. All these steps are aimed at ensuring driving comfort and increasing the overall level of safety during movement.

The last but not least important element of modern electric transport is the charging infrastructure. The extensive and powerful

network of charging stations is the key to ensuring the smooth operation of electric transport. In our time, there are several types of charging stations according to the electrotechnical principle and the corresponding charging speed: slow and fast. Although now, ultra-fast stations known as High-Power DC (HPC) are also often distinguished separately. «AC», that are slow charging stations, are designed, in most cases, for common household use. They can charge a vehicle accumulator in a few hours. As a rule, «AC» stations have a power of 2-22 kW. «DC», that are fast charging stations, are designed in most cases for use in public and various commercial locations. They can charge a vehicle battery to 80% in less than an hour, which is of course much better result compared to ordinary «AC» chargers. As a rule, «DC» stations have a power of 50-120 kW. The direct difference between the «AC» and «DC» chargers is shown in Fig. 3.

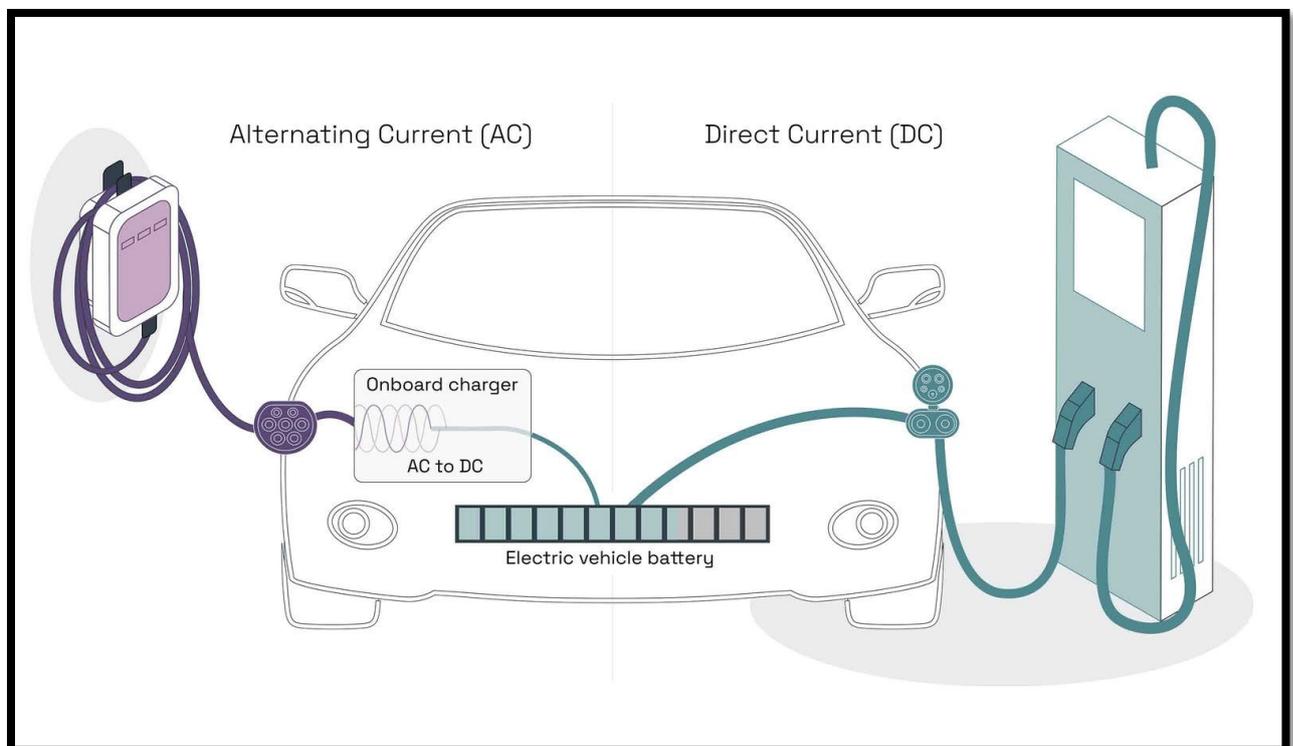


Figure 3 – Difference between AC and DC chargers

Source: <https://www.petalite.io/resources/insights/what-is-dc-charging>

And undoubtedly, the best ones today are ultra-fast charging stations. High Power

Charging (HPC) is a subtype of «DC» and is characterized by much higher power. They

are capable of charging a vehicle's battery in just 20-35 minutes, which is very important for time-sensitive or simply long-distance routes. Usually, HPC stations have a power of 150-350 kW.

Taking into account all of the above-mentioned information, it can be underlined that, compared to traditional transport, electric transport clearly stands out with its innovative solutions and technologies in the field of accumulators, electric motors, software, and charging infrastructure. Significant progress in these spheres has made it possible to adapt electric transport to the expectations of buyers and the global

challenges that humanity faces. This has contributed to its widespread use in our time.

Electric transport is changing the traditional mobility system and making it more advanced. In comparison with traditional transport powered by fossil fuels, it has a wide range of advantages. Many of these advantages cover ecological, economic, and social aspects, which are undoubtedly important for the development of humanity in the direction of green logistics and sustainable development. That is why the decision was made to briefly summarize the key advantages of road electric transport in Table 2.

Table 2. Key advantages of road electric transport

Type	Advantages
Ecological	<ul style="list-style-type: none"> - Minimal level of environmental pollution. - Absence of greenhouse gas emissions. - Reduction of noise levels. - Possibility of integration into renewable energy systems. - Reduction in the use of fossil fuels. - Stimulation of the development of innovative solutions. - Reducing the carbon footprint through the use of renewable energy sources.
Economic	<ul style="list-style-type: none"> - Lower maintenance costs. - Lower operating costs. - Stable electricity prices. - High energy efficiency. - No direct dependence on gas stations. - Availability of government incentives (in many countries). - Reduced customs duties (in many countries). - Presence of a wide range of investors who are ready to invest in the development of this area.
Social	<ul style="list-style-type: none"> - Raising environmental awareness of the society. - Development of innovative transport infrastructure. - Increased mobility of citizens. - High accessibility of transport for people with disabilities. - Quiet urban space. - Modernization of cities and communities. - Stability and enhancement of national security. - Improvement of citizens' health by reducing the level of air pollution. - Creation of a huge number of workplaces in various high-tech industries.

Source: Developed by Vladyslav Marchenko

Based on all of the above information, it can be emphasized that road electric transport not only allows to reduce the negative impact of society on the environment, but also provides a wide range of economic and social benefits for citizens. Its high-quality implementation in the logistics

system positively contributes to humanity in its task of achieving sustainable development goals.

The next step towards a full-fledged disclosure of the chosen topic of the article was a brief explanation of the global state of the road electric transport market,

presentation of the share of electric transport in the transport sector, and listing of key players in this market. At present, the road electric transport market is developing at a very rapid pace and shows a serious growth trend. Such intensive and even dynamic development is connected with different innovations in this field, the creation of the appropriate transport infrastructure, an increase in citizens' demand for energy independence, the strengthening of environmental legislation, and the polarization of this type of transport among the population.

Electric car sales neared 14 million in 2023, 95% of which were in China, Europe and the United States [21]. This is an unprecedented indicator. Experts agree that if the political course of key players in this market remains positively oriented towards green development, then by 2030 the share of electric vehicles in light transport sales could reach up to 40% which is a phenomenal result. The situation with electric freight transport is more complicated. Although its sales are also growing, it is clear to everyone that this results are undoubtedly dependent on the development of a new charging infrastructure. To ensure the smooth operation of freight transport, appropriate large capacities, well-equipped charging hubs on highways, and modern depots are needed. Such changes obviously have a strong impact on the energy market and are therefore being implemented rather gradually. Electricity consumption continues to grow, while demand for fossil fuels is expected to slowly decline in the future.

Today, even those companies that had previously not taken these tendencies into account have begun to consider electric transport as an integral part of the logistics sector. We are now seeing the intentions of many market players to start investing their funds in this direction, especially in the creation of new transport models and the production of accumulator batteries. Those representatives who have already created

production capacities are planning to improve and expand them in the future.

An important factor was the emergence of global competition in these sectors, since 20 years ago this entire field was practically empty and most of its niches were simply free. But now competition exists not only with traditional car companies, but also within the electric transport market itself.

The course towards green logistics is becoming increasingly entrenched in the policies of many developed countries. Every year, they find more and more different opportunities to stimulate the mass production of electric transport vehicles and the development of the corresponding charging infrastructure. This manifests itself not only in the form of increased direct investments, but also in various support programs for this area. The most successful examples of such initiatives include tax incentives, subsidies, localization of production, zero-emission standards, etc.

Experts predict that if current conditions continue and government representatives maintain their positive political will toward such changes, the number of electric vehicles on the roads will exceed 100 million units in the coming years. The share of electric freight transport will also increase, as its use is crucial for commercial operations and reducing humanity's dependence on fossil fuels.

Therefore, based on the above-mentioned information, it can be highlighted that the road electric transport market continues to grow and improve. This is clearly evident not only in the number of new electric vehicles and strong competition in the global market, but also in the development of all possible new technological solutions. Despite the existence of serious challenges on this path, it is clear that the prospects in the field of electric transport are simply enormous, especially in the light and heavy transport segment, the development of which could change our lives forever.

An essential step towards the full exploration of the article's topic is the analysis of the share of electric transport. After

conducting a relevant study of trustworthy open sources of information, it can be confirmed that today the sales of this type of

transport demonstrate rapid growth, which can be clearly seen in Table 3.

Table 3. Approximate sales of electric vehicles in 2020-2024

Year	Sales of electric vehicles
2020	~ 3 million units
2021	~ 6,6 million units
2022	~ 10 million units
2023	~ 14 million units
2024	~ 17 million units

Source: created by the author based on [22-26].

However, at the same time, it should be emphasized right away that the specified number of electric transport vehicles is a total amount, and sales rates vary depending on the specific segment. In other words, sales rates for passenger cars are fundamentally different from those for freight transport.

There were about 58.1 million electric vehicles in operation worldwide in 2024 [27]. With the acceleration of the pace of introduction of low-carbon technologies in transport, their number continues to grow. Passenger cars are currently the most popular, mass-market, and developed segment that exists at the current time. In 2024, China was the absolute leader in this market, with the United States and the European Union remaining in second and third place.

The electric freight transport segment is also in incredible demand on the market, but it still lags significantly behind in sales due to its technical limitations. Logistics companies want to immediately receive full-fledged vehicles with powerful accumulators that can not only ensure reliable transportation for long distances but also charge quickly. Therefore, electric trucks are currently actively used on short urban and regional routes.

The spread of electric public transport shows quite good results. Electric buses have already proven their effectiveness in practice many times around the world. Such countries as China, South Korea, India, and the

Netherlands are actively implementing this type of transport as part of their green city policies.

A similar situation can be found in the case of taxi electrification. This has become extremely common in large cities where the appropriate modern infrastructure and services have been created. Developed cities such as Shenzhen, London, New York, Hamburg, and others are particularly famous for this.

Thus, based on the above data, it can be underscored once again that the share of electric vehicles in the transport sector continues to grow. This growth is irregular and depends on the specific segment. Currently, passenger transport is developing most actively, while the electric truck segment still requires appropriate technological development.

A very important element of this article is the disclosure of key players of the electric vehicle market. After analysing open sources, it becomes clear that China, the US, and the European Union remain the undisputed leaders in this field today. China has a simply colossal electric transport market, which is significantly ahead of all its competitors. It is not only famous for its large number of local manufacturers, but also for its strong state support. The electric transport market in the US is also growing strongly. Investments are being made in new technologies, innovative

solutions, and the construction of high-quality infrastructure. The European Union is known for its active work on the implementation of environmental legislation and green standards. The development of electric transport in the EU is achieved through significant subsidies, investments, and flexible tax policies.

Speaking about charging infrastructure manufacturers, it is worth mentioning such well-known companies as: ChargePoint, Tesla, ABB, Siemens, EVBox, EO Charging, Blink Charging, BYD, Star charge ra NIO.

And, of course, some of the most famous and largest electric vehicle manufacturers are shown in Fig. 4.



Figure 4 – Famous electric vehicle manufacturers
Source: Developed by Vladyslav Marchenko

Therefore, summarizing the above-mentioned information, it can be noted that the electric transport market continues its active development. The transformation of the transport industry is proceeding successfully and gradually. More and more companies see replacing traditional transport powered by fossil fuels as an important step towards building a sustainable future.

The next essential step in this article is to explain the current challenges that stand on the way of the development of electric road transport. Although significant progress has

been made in recent years in improving electric transport and its high-quality integration into the global transport network, it must be acknowledged that this process has not been easy. A large number of complex problems have stood and continue to stand on this path. This list of challenges is truly massive and diverse. It starts with economic and political barriers and ends with technological difficulties. A complete list of key challenges that stand on the way of the development of electric transport is shown in Table 4.

Table 4. A list of key challenges that stand on the way of the development of electric transport

Category	Challenge
Technological challenges	Limited range
	Expensive accumulators
	Gradual battery degradation
	Poor development of the sphere of accumulator recycling
	Reduced reliability in cold climates
Market and economic challenges	High price of electric vehicles
	Lack of competition in the market for critical raw materials
	Poorly formed electric transport sector in developing countries
	Not fast enough renewal of vehicle fleet models
	High dependence of manufacturers on government support
Infrastructure challenges	Inconsistent distribution of charging infrastructure across cities and regions
	Still low number of charging stations
	Higher pressure on the electric grid
	Lack of clear standardization of charging connectors
	Small quantity of fast chargers
Energy challenges	Many countries use fossil fuels to generate electricity
	Low share of «clean» electricity that is used in charging networks
	Need to upgrade the power grid system
	Difficulty in establishing local battery production
Legal and regulatory challenges	Complexity of certification and customs barriers
	Fundamentally different levels of government support for electric transport
	Lack of a long-term strategy for the development of electric transport in many countries
	Different regulations in terms of battery recycling
	Poor coordination of existing charging infrastructure standards
Behavioural and social challenges	Long-term adaptation of businesses to the new direction of logistics development
	Public scepticism about electric transport and its reliability
	Outdated stereotypes about the extremely high cost of maintaining electric transport
	Lack of experience in using this type of transport and lack of reliable information

Source: Developed by Vladyslav Marchenko

Thus, the analysis of existing challenges has shown that the development of road electric transport does indeed face a complex set of serious, interrelated challenges. Although these problems are significant at present, they can all be overcome over time through technological progress, active participation of the private sector, and

government support. Implementation of various measures to reduce risks requires sufficient costs [28]. The development of electric transport relies entirely on the systematic coordination of actions by the state, technology companies, businesses, and society.

Conclusions. The result of this article was the achievement of all previously identified goals. In this work, it was clearly stated that today humanity faces such global challenges as environmental pollution, climate change, and depletion of natural resources. Their gradual worsening has led to terrible consequences, prompting scientists to seek all possible solutions that could contribute to the sustainable development of humanity. The widespread adoption of the new concept of green logistics has had a positive impact on the current situation. Electric road transport has become an example of an effective tool for countering the global threats mentioned above and has emerged as a key instrument necessary for achieving sustainable development goals. The analysis performed in this paper confirmed this, showing electric transport as a key element of green logistics and indicating its importance in the context of achieving sustainable development goals. The conducted research revealed the importance of electric transport for the

modern world, demonstrated its high relevance, showed basic technological foundations and explained the current situation on the global road electric transport market. The analysis showed that modern road electric transport has had a rather complex history. Its development has been quite long, difficult, and multi-layered, including periods of rapid growth as well as periods of declining interest in this area. The study of the main advantages of road electric transport and barriers that stand on the way of its development clearly demonstrated that despite significant progress in this sphere, humanity still has a lot of work to do in this regard. If global trends remain in place or even intensify, there is no doubt that these obstacles will gradually decrease. Today, electric transport opens up serious opportunities for achieving a sustainable and environmentally friendly future. That is why it is so important to continue to focus the scientific community's attention on this topic.

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ADAPTATION OF GLOBAL LOGISTICS SYSTEMS TO GEOPOLITICAL AND CLIMATE CHALLENGES: STRATEGIES OF RESILIENCE, DIVERSIFICATION AND RISK MANAGEMENT IN CONDITIONS OF INSTABILITY

Olena Harazha, Dmytro Shevchuk. «*Adaptation of global logistics systems to geopolitical and climate challenges: strategies of resilience, diversification and risk management in conditions of instability*». The article analyzes the adaptation of global logistics systems to geopolitical and climatic challenges based on a strategy of resilience, diversification and risk management in conditions of instability.

The economic stability of national economies, entire industries and individual enterprises is under threat due to dependence on certain suppliers and transport routes, lack of diversity of supply sources, low level of implementation of digital technologies in risk management processes and leveling of environmental conditions. The current challenges are the processes of developing strategies that can adapt global logistics systems to the latest requirements of the modern world by creating comprehensive approaches to sustainability based on the use of various transport corridors and suppliers, the use of the latest innovative technologies for forecasting and risk management, the introduction of alternative environmentally safe solutions, the formation of flexible levers for crisis management. Therefore, the main problem is to adapt global logistics systems to geopolitical and climatic challenges through a balance of sustainability, flexibility, efficiency, economic security and benefits taking into account local needs and global interests. Ultimately, to solve it, it is necessary to take into account a set of economic, technological, environmental, and political instruments with a rethinking of the participation of logistics as the main instrument of global stability in the conditions of uncertainty of the modern global economy.

The aim of our work is to study the adaptation of global logistics systems to geopolitical and climatic challenges based on the application of a strategy of resilience, diversification and risk management in conditions of instability.

The disclosure of the goal and the solution of the tasks were carried out on the basis of a comprehensive and systematic methodological approach with a set of methods of induction and deduction, abstraction, concretization, formalization and analogy. The scientific developments of domestic and foreign scientists, standards and rules served as reference material.

According to the results of the study, three main directions of adaptation of global logistics systems to geopolitical and climatic challenges were identified: strategies of sustainability, diversification and risk management in conditions of instability. It was found that the sustainability strategy combines the sectors of the national economy, legal government activities and coordination of transport processes and international transport organizations. It was proven that the sustainability strategy includes diversification, transparency of logistics processes, reserves and flexibility, planning and risk management, strategic partnership and cooperation with international partners. It was found that diversification involves the creation of a strategy based not on a single activity, but on the multidimensionality of different types of business in the global market. It was substantiated that territorial diversification is able to place production in different countries, which eliminates the risks of temporary closure of individual regions, climate change or sanctions. The risk management of global logistics systems is characterized, which involves a comprehensive approach to identifying, monitoring, analyzing and controlling the international delivery of goods under conditions of uncertainty with the aim of fast, safe delivery with minimal losses.

The key provisions for adapting global logistics systems to geopolitical and climate challenges in an environment of instability are resilience, diversification and risk management strategies that take into account geopolitical challenges and sanctions, climate change and natural disasters, transition to green logistics, create backup routes and expand the supplier base, implement anti-crisis strategies, insure logistics risks and improve staff qualifications.

Keywords: sustainability, strategy, climate, instability, diversification, international cooperation, transport, cargo

Олена Гаража, Дмитро Шевчук. «Адаптація глобальних логістичних систем до геополітичних та кліматичних викликів: стратегії стійкості, диверсифікації та управління ризиками в умовах нестабільності». У статті аналізується адаптація глобальних логістичних систем до геополітичних та кліматичних викликів на основі стратегії стійкості, диверсифікації та управління ризиками в умовах нестабільності.

Економічна стабільність національних економік, цілих галузей та окремих підприємств перебуває під загрозою через залежність від певних постачальників та транспортних маршрутів, відсутність різноманітності джерел постачання, низький рівень впровадження цифрових технологій в процеси управління ризиками та нівелювання екологічних умов. Актуальними викликами стають процеси розробки стратегій, які мають змогу адаптувати глобальні логістичні системи до новітніх вимог сучасного світу шляхом створення комплексних підходів до стійкості на основі застосування різних транспортних коридорів і постачальників, застосування новітніх інноваційних технологій щодо прогнозування та управління ризиками, впровадження альтернативних екологічних безпечних рішень, формування гнучких важелів управління кризовими ситуаціями. Відтак, основна проблема полягає в адаптації глобальних логістичних систем до геополітичних та кліматичних задач через баланс стійкості, гнучкості, ефективності, економічної безпеки та вигоди з урахуванням локальних потреб та глобальних інтересів. Зрештою, для її вирішення треба враховувати сукупність економічних, технологічних, екологічних, політичних

інструментів з переосмисленням участі логістики як головного інструменту глобальної стабільності в умовах невизначеності сучасної глобальної економіки.

Метою нашої роботи є вивчення адаптації глобальних логістичних систем до геополітичних та кліматичних викликів на основі застосування стратегії стійкості, диверсифікації та управління ризиками в умовах нестабільності.

Розкриття мети та вирішення поставлених завдань проведено на основі комплексного та систематичного методологічних підходів із сукупністю методів індукції та дедукції, абстрагування, конкретизації, формалізації та аналогії. Довідковим матеріалом слугували наукові розробки вітчизняних і закордонних вчених, стандарти та правила.

За результатами дослідження виділено три основні напрями адаптації і глобальних логістичних систем до геополітичних та кліматичних викликів: стратегії стійкості, диверсифікації та управління ризиками в умовах нестабільності. Виявлено, що стратегія стійкості поєднує галузі національної економіки, правову урядову діяльність та координування транспортних процесів і міжнародних транспортних організацій. Доведено, що стратегія стійкості включає диверсифікацію, прозорість логістичних процесів, резерви та гнучкість, планування та управління ризиками, стратегічне партнерство та співпрацю із міжнародними партнерами. Виявлено, що диверсифікація передбачає створення стратегії, що заснована не на одній діяльності, а багатомірності різних видів бізнесу на світовому ринку. Обґрунтовано, що територіальна диверсифікація спроможна розмістити виробництва у різних країнах, що усуває ризики від тимчасового закриття окремих регіонів, кліматичних змін або санкцій. Охарактеризовано управління ризиками глобальних логістичних систем, що передбачають комплексний підхід до визначення, спостереження, аналізу та контролю за міжнародною доставкою товарів в умовах невизначеності з метою швидкої, безпечної доставки з мінімальними збитками.

Ключовими положеннями адаптація глобальних логістичних систем до геополітичних та кліматичних викликів в умовах нестабільності стають стратегії стійкості, диверсифікації та управління ризиками, які ураховують геополітичні виклики та санкції, кліматичні зміни та природні катастрофи, переходять до зеленої логістики, складають резервні маршрути та розширюють базу постачальників, впроваджують антикризові стратегії, страхування логістичних ризиків та підвищують кваліфікацію персоналу.

Ключові слова: стійкість, стратегія, клімат, нестабільність, диверсифікація, міжнародне співробітництво, транспорт, вантаж

Introduction. Modern transport management is influenced by global processes of the world economy. Constant transformations and globalization of logistics systems are due to geopolitical and climatic changes. The stability of transport corridors, transparency of international relations, a small degree of natural risks form the basis of the traditional model, which is not flexible in the conditions of uncertainty of modern world development. Given the combination of negative factors of geopolitical tension, trade competition, the introduction of sanctions, blocking of transport networks due

to military conflicts, traditional logistics supply chains are being disrupted, posing a threat to the continuity of the production process and ensuring the availability of commodity products on the global market. At the same time, climatic changes are taking place in the world, which significantly affect logistics processes due to the intensification of extreme weather phenomena, rising sea levels, increasing droughts and floods, reducing the efficiency of sea, river and land transportation, the need to modernize transport infrastructure, and increasing the cost of insurance services. Therefore, modern

logistics systems are immersed in multidimensional instability and uncertainty with a set of interacting and complementary risks of a complex nature. Today shows that the vast majority of modern logistics models do not meet the standards of sustainability and flexibility for effective functioning and rapid response to these challenges, which is the current problem of this study. The economic stability of national economies, entire industries and individual enterprises is under threat due to dependence on certain suppliers and transport routes, lack of diversity of supply sources, low level of implementation of digital technologies in risk management processes and leveling of environmental conditions. The current challenges are the processes of developing strategies that can adapt global logistics systems to the latest requirements of the modern world by creating comprehensive approaches to sustainability based on diversifying the use of transport corridors and suppliers, applying the latest innovative technologies for forecasting and risk management, implementing alternative environmentally safe solutions, and forming flexible levers for managing crisis situations. Therefore, the main problem is to adapt global logistics systems to geopolitical and climatic challenges through a balance of sustainability, flexibility, efficiency, economic security and benefits, taking into account local needs and global interests. To solve it, it is necessary to take into account a set of economic, technological, environmental, political instruments with a rethinking of the participation of logistics as the main instrument of global stability in the conditions of uncertainty of the modern global economy.

Analysis of recent research and publications. Adapting global logistics systems to geopolitical and climatic challenges is the subject of scientific developments and achievements of many domestic and international scholars. Christopher S. Tang, Hau L. Lee, Jing-Sheng Song [1] investigated climate change, which

creates systemic risks for global supply chains, increasing the frequency of extreme weather events, disrupting transportation networks and threatening the reliability of suppliers. Along with this, they indicate that firms should apply resilience strategies, such as diversifying supply locations, investing in predictive analytics and collaborating with stakeholders. Paul R. Kleindorfer, Yossi Sheffi [2] examined the physical impact of climate, which reduces suppliers' revenues and negatively affects downstream customers, demonstrating the interconnectedness of risks in global networks and the urgent need for adaptive logistics strategies. Olena Koval, Andriy Petrenko [3] examined the military conflict in Ukraine, trade conflicts between the US and China, and instability in the Middle East, which are forcing companies to change supply routes, increase insurance costs, and reconsider the diversification of supply chains. Maria Beske, Thomas Seuring [4] examined climate change, which requires comprehensive strategies that combine environmental sustainability with economic efficiency, highlighting the role of logistics in balancing sustainability and competitiveness. Daniel Müller, Sophie Hartmann [5] examined the logistics sector, which plays a crucial role in global trade but faces serious challenges related to geopolitical instability and climate risks, requiring new models of crisis management and resilience. Peter Wagner, Li Zhang [6] examined global supply chains that are becoming increasingly uncertain due to constant changes in international trade and geopolitical upheavals, making resilience and diversification of utmost importance. Alan McKinnon [7] analyzed logistics, which is both a contributor to and a victim of climate change, but can also play a key role in decarbonization and adaptation strategies. Łukasz Bednarski, Samuel Roscoe, Constantin Blome, Martin C. Schleper [8] studied the impact of geopolitical upheavals on supply chains, which can be mitigated through: reorganizing supply chains, including regionalization, backshoring, and moving away from just-in-time supply models, as well

as implementing new technologies such as blockchain, 3D printing, and artificial intelligence to increase supply chain transparency and develop modular manufacturing. Seyed Ashkan Hosseini Shekarabi, Reza Kiani Mavi, Flavio Romero Macau [9] identified three distinct research clusters: supply chain resilience optimization, supply chain technology resilience implementation, and fault tolerance and risk management strategies. Mariia Hryhorak, Alona Dimitrova [10] identified effective risk management techniques such as supply chain diversification, alternative routing, and insurance mechanisms. They examined risk management in the import of industrial fasteners, illustrating the stages of cooperation with freight forwarders and carriers, partner selection, and response to faults, demonstrating approaches that can be used to minimize the impact of risks. However, the adaptation of global logistics systems to geopolitical and climatic challenges requires in-depth study, based on scientific developments by scientists from different countries of the world, which shows the relevance of the topic under study. The main areas of adaptation of logistics systems are: strategies of sustainability, diversification and risk management in conditions of instability.

The purpose of the article is to study the adaptation of global logistics systems to geopolitical and climatic challenges based on the application of a strategy of resilience, diversification, and risk management in conditions of instability.

Presentation of the main research material. Geopolitical challenges are modern problems that are formed at the intersection of geography, economics, politics, security of entire states and individual territorial entities within them, trying to adapt strategies to protect national interests at the state level in terms of using resource potential and competitiveness on the world stage from war, conflicts, migration crises and energy dependence. International logistics systems are losing their own supply chains and

increasing operational risks due to geopolitical tensions and military conflicts. Therefore, in international logistics there is a need for risk management, analysis and planning, comprehensive interaction between state bodies, logistics and international institutions to increase the effective operation of logistics systems in complex geopolitical systems. Increasing costs for logistics procedures and disruption of trade processes of international deliveries can cause sanctions, increased tariffs and trade barriers. Logistics companies have to look for additional delivery methods due to the increase in customs tariffs, which affects the cost of trade. At the same time, the transportation of goods and international trade may be significantly reduced due to sanitation restrictions that affect trade flows and the competitiveness of suppliers. Therefore, these complex tasks may prompt the development of new strategies and flexible cooperation between different organizations to form optimal logistics solutions for the elimination of trade barriers. It is very important for logistics companies to retain and increase the range of customers, but political stratification and armed conflicts in cargo transportation areas cause delays and losses, changes in routes and supply chains. In some conflict areas, borders are closed and transport routes are stopped, so it is necessary to develop new ways of delivering goods and increase the cost of logistics services. Big business finds itself in conditions of uncertainty and under the influence of many risks, which require new ways of developing optimal supply strategies and routing cargo delivery. The impact of political complications and military conflicts on the supply chain can be mitigated by implementing risk management strategies, implementing additional protection conditions and multifaceted routing. Along with this, the establishment of global international relations and the deepening of globalization processes will develop stability and security in the regions, contributing to their sustainable development and socio-

economic stability. At the same time, international logistics companies are developing on the basis of various trade agreements while adapting to the variability of the geopolitical situation on the world stage. The growth of demand for logistics services occurs by creating favorable conditions for free trade and the development of export-import relations, attracting investments in trade and warehouse infrastructure. At the same time, wider opportunities are opening up for entering new markets, increasing trade turnover, which causes an increase in demand for logistics services for clients who aim to expand their business by attracting the latest technologies and reaching the international level of trade and operational activities.

The sustainability of global logistics systems is based on cooperation between government organizations and departments, various sectors of the national economy and international transport organizations. Timely exchange of information and joint training on transportation safety in regions with a conflict situation consolidates the development of initiatives in common standards that regulate emerging risks and the safety of cargo transportation in hot regions. To manage and predict risks, instantly respond to unforeseen events, and eliminate the crisis from instability, the latest innovative technologies, artificial intelligence and investment in transport and warehouse infrastructure are being introduced into global logistics systems. Strengthening the sustainability of logistics systems is based on cargo insurance in case of delays or loss of goods and appropriate financial measures to prevent possible losses from geopolitical conflicts. Sustainability strategies are based on:

1. diversification, which involves reducing dependence and risks that have a common route or supplier. Diversification of suppliers involves eliminating disruptions in the supply chain when one supplier or region drops out. Therefore, several suppliers of raw materials located in different territories of the country are involved. Diversification of routes and

modes of transport involves involving different modes of transport and transport corridors, ports and distribution centers for logistics activities with the possibility of changing the route in case of blocking the first route.

2. transparency and visibility of logistics processes. Implementation of the latest real-time tracking technologies based on IoT sensors, GPS trackers, blockchain and control tower systems (Control Towers) in order to continuously monitor the location of goods, their stock levels in the warehouse and possible risks along the entire supply chain. Timely exchange of data between customers, manufacturers, suppliers and logistics operators. Conducting analytical actions and forecasts regarding the processing of large data sets and predictive modeling in order to eliminate possible risks (delays due to climate change or political crisis).

3. reserves and flexibility. In order to quickly respond to unforeseen circumstances, reserve capacities are created. To avoid shortages of goods during disruptions in supply chains, stocks and back-ups of critical goods are placed in warehouses and distribution centers. Thus, additional volumes of goods are created that can be quickly changed and sent to different supply chains in the event of their breakdowns or new warehouse facilities are added. An additional important element is the multi-professionality of the working staff, who reacts to changes and ensures the continuity of work processes.

4. Planning and risk management. Constant audit and analysis of shortcomings in supply chains, such as climatic and territorial risks, dependence on technologies, points of failure, help to form rules for the rapid elimination of such shortcomings. The use of simulation modeling methods checks the reliability of the selected route and provides possible new paths in case of emergencies.

5. Strategic partnership and cooperation with international partners. In this case, sustainability places responsibility on all

participants in the logistics process. Carriers, suppliers and forwarders form strong and trusting relationships aimed at streamlining operations and reducing uncertainty through planning, forecasting and increasing inventories of goods.

The main indicators of resilience are recovery time after a failure, transparency in the supply chain, reliability in providing stable work between suppliers and carriers in the provision of transport services. To implement resilience strategies, the latest artificial intelligence and machine learning technologies are used to forecast demand and supply, optimize given routes and identify risks and climate disruptions. Additionally, digital twins can be implemented to test risks and the possibility of eliminating them. In order to quickly distribute and access information anywhere in the world based on cloud technologies.

Diversification of global logistics systems involves creating a strategy that focuses not on a single activity, but on the multidimensionality of different types of business in the global market. Territorial diversification tries to place production in different countries, which eliminates risks from temporary lockdowns of individual regions, climate change or sanctions. Diversification of hubs and routes involves cooperation with different ports and channels, combining different types of transport, developing new corridors and routes. Diversification of partners and carriers through the distribution of transportation between different lines and forwarders, forming their own fleet of vehicles in logistics units to gain independence from market prices and lack of places on transport. Diversification of stocks and warehouses is based on the creation of a network of smaller warehouses located closer to sales markets, and the concentration of stocks in warehouses to ensure continuous operation for several months in the event of a disruption in the supply chain. The problems of diversification consist of increased costs, reduced quality control and standards,

negative environmental consequences. Diversification provides insurance against risks, but increases the cost of the product in stable times, but prevents the liquidation of the company during crisis years.

Risk management of global logistics systems involves a comprehensive approach to identifying, monitoring, analyzing and controlling the international delivery of goods under conditions of uncertainty with the aim of fast, safe delivery with minimal losses. Risk management is based on four main areas: 1. Identification, which finds unstable chains (dominance of one carrier, cyberattack risks). 2. Analysis, which provides an assessment of the occurrence of an event and the consequences of losses. 3. Methods of counteracting negative situations, which include insurance, avoidance or resolution of the risk. 4. Monitoring the environment on an ongoing basis to avoid new threats. To address the negative impact, operational methods (strategic redundancy, logistics diversification and flexibility), technological methods (AI - analytics, digital twins, cybersecurity), partner methods (3PL and 4PL operators), collaborative planning are used. The most commonly used strategies are avoiding risky activities, reducing the likelihood of consequences through the use of GPS trackers on containers to prevent theft, transferring responsibility to a third party through insurance or outsourcing, and taking on risk to make a profit based on the unique price of a new supplier.

Conclusions. Modern economic development requires new conditions for transport activities and transportation of goods, cargo and passengers. The rapid development of logistics companies in conditions of uncertainty and under the influence of economic globalization creates the basis for the adaptation of global logistics systems to the variability of geopolitical changes and climatic conditions based on strategies of sustainability, diversification and risk management. Therefore, the first element of the adaptation of global logistics systems is sustainability, which combines the sectors of

the national economy, legal government activities and coordination of transport processes and international transport organizations. The development of modern sustainability strategies, which include diversification, transparency of logistics processes, reserves and flexibility, planning and risk management, strategic partnership and cooperation with international partners. At the same time, the sustainability strategy includes the terms of recovery after a break in supply chains, transparency of work performance by the supplier, reliability of transport services and stable cooperation between suppliers and carriers. The next element of the adaptation of global logistics systems is diversification, which involves the creation of a strategy based not on a single activity, but on the multidimensionality of different types of business in the global market. One of its types is territorial diversification, which is able to place production in different countries, which eliminates the risks of temporary closure of individual regions, climate change or

sanctions. The peculiarity of diversification is that it provides insurance against risks, but increases the cost of the product in stable times, but prevents the liquidation of the company during crisis years. A crucial element of the adaptation of global logistics systems is the risk management of global logistics systems, which involves a comprehensive approach to the definition, monitoring, analysis and control of international delivery of goods in conditions of uncertainty for the purpose of fast, safe delivery with minimal losses. Risk management is based on four main areas: identification, analysis, methods of countering negative situations, and observation. Promising directions for adapting global logistics systems to geopolitical and climatic challenges based on the application of a strategy of resilience, diversification, and risk management in conditions of instability are the deepening of international ties and regulatory support, the application of world experience in transparency, and international cooperation.

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THE ROLE OF HUMAN CAPITAL IN A PROACTIVE APPROACH TO MANAGING ECONOMIC SECURITY THREATS: INTEGRATING AGILITY AND RISK MANAGEMENT

Ganna Gurina, Serhii Podrieza, Oleksii Tseluiko, Nazarii Liskovych. «The role of human capital in a proactive approach to managing economic security threats: integrating agility and risk

management». The article explores the role of human capital in a proactive approach to managing economic security threats during martial law in Ukraine. The processes of integrating agility and risk management at enterprises are analyzed. The focus is on aviation enterprises and the human capital of this industry. In modern conditions, human capital is not only the core of national security, but also the foundation of a proactive approach to managing threats to economic security. Instead of a reactive response to crises, strategic investment in education, vocational training and healthcare forms an intellectual resource capable of anticipating the challenges of military and post-war recovery. This provides the state with the tools necessary for effective identification and elimination of both traditional and new threats in a dynamic environment. The development of human capital directly integrates the principle of agility into the economic system. Highly qualified aviation specialists, possessing advanced technologies and a deep understanding of global markets, ensure the agility of state policy in the civil and defense sectors. Their ability to quickly adapt to changes in international law and the global political environment enhances the country's influence and economic resilience.

Keywords: human capital; economic security; proactive management; risk management; agility; aviation enterprises; aviation personnel; national security; post-war recovery; strategic investment; vocational training; technological competence; economic resilience; defense sector; adaptation

Ганна Гуріна, Сергій Подреза, Олексій Целуйко, Назарій Ліскович. «Роль людського капіталу в проактивному підході до управління загрозами економічній безпеці: інтеграція гнучкості та управління ризиками». У статті досліджується роль людського капіталу в проактивному підході до управління загрозами економічній безпеці під час воєнного стану в Україні. Аналізуються процеси інтеграції гнучкості та управління ризиками на підприємствах. Сфокусована ціль на авіаційних підприємствах та людському капіталі саме цієї галузі. В сучасних умовах людський капітал виступає не лише стрижнем національної безпеки, а і фундаментом проактивного підходу до управління загрозами економічній безпеці. Замість реактивного реагування на кризи, стратегічне інвестування в освіту, професійне навчання та охорону здоров'я формує інтелектуальний ресурс, здатний випереджати виклики воєнного і повоєнного відновлення. Це забезпечує державу інструментарієм, необхідним для ефективної ідентифікації та нівелювання як традиційних, так і нових загроз у динамічному середовищі. Розвиток людського капіталу безпосередньо інтегрує принцип гнучкості в економічну систему. Висококваліфіковані фахівці авіаційного профілю, володіючи передовими технологіями та глибоким розумінням глобальних ринків, забезпечують гнучкість державної політики в цивільному та оборонному секторах. Їх здатність швидко адаптуватися до змін у міжнародному праві та глобальному політичному середовищі посилює вплив та економічну стійкість країни.

Ключові слова: людський капітал; економічна безпека; проактивне управління; управління ризиками; гнучкість; авіаційні підприємства; авіаційний персонал; національна безпека; післявоєнне відновлення; стратегічні інвестиції; професійна підготовка; технологічна компетентність; економічна стійкість; оборонний сектор; адаптація

Introduction. Investments in the intellectual and physical development of the population constitute a fundamental element of the state-level risk management system. By enhancing the skills and knowledge of citizens within strategic sectors, a nation not

only mitigates internal risks but also emerges as an active agent in ensuring global stability. This approach demonstrates that human capital development is not a matter of arbitrary choice but a non-alternative strategy for any state striving to secure a prosperous

and safe future. The dividends of such investments are manifested in improved macroeconomic indicators, the reduction of social inequality, and the formation of a political system resilient to external shocks. Simultaneously, the implementation of this strategy under martial law necessitates a specialized approach to risk management. It is imperative to account for critical threats such as migration processes, the depletion of human potential, and the destruction of educational infrastructure. These factors render the integration of risk management into the processes of human capital reproduction vital for preserving the economic security of the state.

Literature review. Significant contributions to the conceptualization of human capital development and specific aspects of its management have been made by such prominent Ukrainian scholars as V. Antoniuk, K. Bodnar, O. Grishnova, L. Shevchuk, and others. In recent years, scholarly focus has increasingly shifted toward the challenges of human capital management under wartime conditions and during the post-war recovery period.

Purpose and objectives. In the contemporary landscape of global instability, human capital has emerged not merely as a social category but as the fundamental core of national security across multiple dimensions. Strategic investment in the intellectual and physical development of the population constitutes a vital element of the state-level risk management system, providing the necessary tools to address both persistent and emerging threats. This is particularly evident in high-tech strategic industries, most notably the aviation sector, where the quality of human capital—comprising highly specialized engineers, pilots, and technical personnel—directly determines a nation's technological sovereignty and its capacity for rapid crisis response. The transformations of the past five years have fundamentally altered the paradigm of human capital perception, evolving it from a secondary resource into a central element of proactive economic

security management. Modern public policy is increasingly anchored in a global consensus: investment in highly specialized skills is a foundational prerequisite for fostering "economic agility." In the aviation industry, this agility is manifested through the ability of personnel to adapt to rapid technological shifts, stringent international safety standards, and the complex logistical challenges imposed by wartime conditions. Academic discourse, supported by the foundational works of Ukrainian scholars such as V. Antoniuk, O. Grishnova and many others, convincingly proves that human-centric development creates a "systemic immunity" against external perturbations. However, implementing such a strategy under martial law necessitates a specialized approach to risk management. The aviation sector faces unique and critical threats, including the massive migration of certified specialists, the destruction of specialized educational infrastructure, and the erosion of professional competencies due to the suspension of civil flights. Integrating risk management into the reproduction of aviation-related human capital is therefore vital for preserving the state's long-term economic security. By strengthening skills in such strategic sectors, a country transitions from passive consequence mitigation to proactive security contour modeling. Ultimately, fostering a resilient and innovation-oriented workforce in aviation and other high-stakes industries serves as the primary instrument for post-war recovery, transforming potential risks into opportunities for a profound technological and social leap.

Results, analysis, and discussion. The transformations of the past five years have fundamentally altered the paradigm of human capital perception, evolving it from a secondary resource into a central element of proactive economic security threat management. Modern public policy is anchored in a global consensus: investment in the nation's intellectual and physical potential is a foundational prerequisite for fostering economic agility. Academic

discourse over the last fifteen years convincingly proves that advancements in education and healthcare not only enhance individual productivity but also cultivate "systemic immunity" against external perturbations, ensuring stability at both national and regional levels.

The adoption of this approach is critically relevant for Ukraine, where the formulation of new public policy must be grounded in the principles of strategic risk management. In the context of post-war recovery, the human factor becomes the primary instrument for neutralizing economic threats. Qualified, healthy, and innovation-oriented citizens serve as the bearers of adaptive potential, enabling the state system to maintain flexibility amidst pervasive uncertainty. Integrating human capital into a comprehensive security strategy facilitates a transition from passive consequence mitigation to proactive security contour modeling. A high level of human resource development bolsters the nation's overall recovery capacity and resilience, transforming potential risks into opportunities for a technological and social leap. Consequently, investment in people emerges as the most effective method for managing long-term threats to economic stability. In the academic discourse, the position presented in [2, 3] appears well-founded, as it conceptualizes human capital as a fundamental determinant of economic and social development. Human capital encompasses not only an educated

labor force but also a system of advanced knowledge, intellectual and managerial tools, as well as institutional conditions that ensure the effective utilization of this potential within public administration and the processes of economic socialization. Within this framework, the contemporary concept of societal development—grounded in theory and oriented toward the practice of public governance—proceeds from the understanding that social progress should not be assessed solely through the lens of material well-being. Increasingly, the development of the individual, their professional competencies, and their capacity for innovative activity is regarded as a key indicator of societal advancement.

These considerations acquire particular relevance in the aviation sector of Ukraine, where human capital plays a strategic role in maintaining the security and resilience of enterprises. Aviation personnel—pilots, engineers, air traffic controllers, and technical specialists—possess highly specialized expertise and undergo lengthy professional training, making the loss of such personnel especially detrimental for the industry. Under wartime conditions, the need to preserve, develop, and adapt this human capital becomes even more urgent, as the competence and resilience of aviation professionals directly influence the ability of enterprises to counter economic threats and sustain the critical functions of aviation infrastructure.

Category	Description
Population Loss	Reduction due to casualties, displacement, and emigration, including loss of trained aviation personnel.
Brain Drain	Highly skilled aviation engineers, pilots, and technicians leaving the country for safer and more stable employment abroad.
Disrupted Education	Interruptions in aviation training programs, closure or relocation of aviation academies, and limited access to simulators and equipment.
Physical Trauma	Injuries and disabilities among aviation specialists working in high-risk operational environments.
Psychological Trauma	Stress, burnout, and PTSD among pilots, air traffic controllers, and technical crews operating under wartime pressure.
Labor Market Instability	Reduced demand for civil aviation services, job losses, and reallocation of aviation staff to military needs.
Infrastructure Damage	Destruction of airports, training centers, airfields, and maintenance facilities critical for aviation workforce development.
Social Fragmentation	Disruption of professional communities and mentorship networks within the aviation sector.
Sector-Specific Vulnerability	Loss of unique expertise due to the long training cycle of pilots and engineers, making replacement extremely difficult.

Figure 1 – Destructive factors impacting the state and development of aviation human capital during wartime.

Within the framework of a proactive approach to threat management, it is critically important to understand why the degradation or insufficient funding of human capital constitutes an existential threat to the economic security of the state. An untimely response to risks in this area leads to the systemic vulnerability of the nation:

- Loss of economic agility: The greatest danger lies in the loss of the economy's capacity for rapid adaptation. Without highly qualified personnel capable of continuous learning, both public and private institutions become rigid. In the event of new threats (technological shocks, pandemics, or military challenges), a country with a low level of human capital agility cannot promptly reorient its production or management

systems, which leads to a prolonged recession.

- Risk of "brain drain": Under conditions of martial law and global competition for talent, human capital migration transforms from a demographic issue into a direct threat to national security. Economic security is based on the ability to create added value. The departure of specialists (especially in STEM, aviation, and medicine) deprives the country of its "innovation engine." This creates a situation where state investments in education made previously effectively subsidize the economies of other countries, leaving the domestic system in a state of resource deficit for recovery.

- Degradation of social resilience: Inequality in access to human capital development creates social rifts. When a

significant portion of the population is excluded from professional development processes, levels of social tension and political populism rise. This makes the political system vulnerable to external hybrid influences and internal destabilization, which serves as a direct threat to economic security.

- Technological lag as a strategic risk: Proactive risk management requires constant modernization. A lack of investment in human

capital makes the implementation of innovations impossible. The country becomes technologically dependent. Under martial law, this translates to an inability to develop and maintain independent defense and energy solutions, making national security critically dependent on external suppliers.

To visualize how human capital (HC) influences security, the following functional relationship can be utilized:

$$S_{econ} = f(HC \cdot A \cdot RM)$$

where:

S_{econ} – level of economic security;

HC – level of human capital (education, health, skills);

A – agility index (speed and flexibility of adaptation);

RM – effectiveness of risk management (ability to mitigate or neutralize threats).

Any decline in the HC indicator automatically nullifies efforts in the realms of agility and risk management. Consequently, investment in human development should not be viewed as a budgetary expense, but rather as a form of national risk insurance.

Conclusions. Human capital plays a decisive role in a proactive approach to managing economic security threats, especially within Ukraine's aviation sector. Aviation enterprises rely heavily on highly skilled pilots, engineers, air traffic controllers, and technical specialists whose expertise cannot be rapidly replaced. In wartime conditions, proactive risk management requires aviation companies to strengthen agility in workforce planning and operational decision-making. The ability to anticipate disruptions - such as personnel shortages, infrastructure damage, or cyber threats - depends directly on the competence and adaptability of aviation professionals. Ukrainian aviation enterprises face unique challenges, as many specialists are mobilized, displaced, or forced to relocate abroad. This increases the urgency of retaining critical talent and developing flexible training systems that can operate even under instability. Agility becomes a strategic asset,

enabling companies to reconfigure teams, redistribute responsibilities, and maintain essential operations despite uncertainty. Human capital also drives innovation in safety protocols, digitalization, and remote operational capabilities, which are vital for economic resilience. Proactive risk management in aviation requires continuous upskilling, especially in areas such as crisis response, cybersecurity, and aircraft maintenance under constrained conditions. Ukrainian aviation specialists demonstrate high adaptability, which strengthens the sector's capacity to withstand economic shocks. However, the loss of experienced personnel poses long-term risks to national economic security. Aviation enterprises must therefore invest in talent retention programs, psychological support, and competitive career pathways. Collaboration with educational institutions is essential to ensure a steady pipeline of new aviation professionals. Ultimately, the integration of agility and risk management transforms human capital into a protective shield for the aviation industry. By empowering aviation specialists, Ukraine enhances both sectoral stability and broader national economic security.

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DIGITAL TRANSFORMATION STRATEGY OF THE CUSTOMER RELATIONSHIP MANAGEMENT SYSTEM

Țirlea Mariana Rodica, Nataliia Trushkina, Oleh Harmash, Yuliya Shkrygun. «*Digital transformation strategy of the customer relationship management system*». In the contemporary digital economy, customer relationship management is undergoing profound transformations driven by changes in consumer behavior, intensifying competition, and the rapid development of digital technologies, data analytics,

and artificial intelligence. Despite the widespread adoption of CRM systems, business practice still demonstrates a fragmented and instrumental approach to the digitalization of customer-related processes, which limits the ability to create long-term customer value and sustainable competitive advantages.

The purpose of this article is to substantiate and develop a digital transformation strategy for the customer relationship management system as an integrated managerial concept focused on the alignment of customer value, customer experience, business processes, data, digital technologies, and organizational change. The methodological framework of the study is based on systemic and process-oriented approaches, as well as methods of analysis and synthesis, structural-logical modeling, and the generalization of scientific publications and expert assessments in the field of digital transformation and CRM.

As a result of the study, a structural-logical model of the CRM digital transformation strategy is proposed, built on the principle of concentric levels with a vertical integrating axis, reflecting the interrelationships between customer value, customer experience, the process-and-data core of CRM, digital technologies, and the strategic and organizational management framework. It is demonstrated that effective digital transformation of CRM should be considered a continuous adaptive process aimed not only at automating customer interactions but also at transforming managerial practices, organizational culture, and the system of personnel competencies.

The scientific novelty of the research lies in the improvement of approaches to shaping a CRM digital transformation strategy through its interpretation as an integrated managerial architecture. The practical significance of the results consists in the possibility of applying the proposed model to the design and implementation of customer-oriented development strategies for enterprises operating in the digital economy.

Keywords: digital transformation; customer relationship management; CRM strategy; customer value; customer experience; omnichannel interaction; customer journey; data management; Big Data; data analytics; artificial intelligence; digital platforms; strategic management; organizational culture; digital competencies; customer orientation; sustainable development.

Цирля Маріана Родіка, Наталія Трушкіна, Олег Гармаш, Юлія Шкригун. «Стратегія цифрової трансформації системи управління взаємовідносинами з клієнтами». У сучасній цифровій економіці управління взаємовідносинами з клієнтами зазнає глибоких трансформацій, зумовлених змінами у поведінці споживачів, посиленням конкуренції та стрімким розвитком цифрових технологій, аналітики даних і штучного інтелекту. Попри широке впровадження CRM-систем, ділова практика й надалі демонструє фрагментарний та інструментальний підхід до цифровізації клієнтських процесів, що обмежує можливості створення довгострокової цінності для клієнтів і стійких конкурентних переваг.

Метою статті є обґрунтування та розроблення стратегії цифрової трансформації системи управління взаємовідносинами з клієнтами як інтегрованої управлінської концепції, орієнтованої на узгодження цінності для клієнта, клієнтського досвіду, бізнес-процесів, даних, цифрових технологій та організаційних змін. Методологічну основу дослідження становлять системний і процесно орієнтований підходи, а також методи аналізу й синтезу, структурно-логічного моделювання та узагальнення наукових публікацій і експертних оцінок у сфері цифрової трансформації та CRM.

У результаті дослідження запропоновано структурно-логічну модель стратегії цифрової трансформації CRM, побудовану за принципом концентричних рівнів із вертикальною інтегрувальною віссю, що відображає взаємозв'язки між цінністю для клієнта, клієнтським досвідом, процесно-даним ядром CRM, цифровими технологіями та стратегічно-організаційним управлінським каркасом. Доведено, що ефективну цифрову трансформацію CRM доцільно розглядати як безперервний адаптивний процес, спрямований не лише на автоматизацію взаємодії

з клієнтами, а й на трансформацію управлінських практик, організаційної культури та системи компетентностей персоналу.

Наукова новизна дослідження полягає в удосконаленні підходів до формування стратегії цифрової трансформації CRM шляхом її трактування як інтегрованої управлінської архітектури. Практична значущість результатів полягає у можливості застосування запропонованої моделі для проектування та впровадження клієнтоорієнтованих стратегій розвитку підприємств, що функціонують у цифровій економіці.

Ключові слова: цифрова трансформація; управління взаємовідносинами з клієнтами; CRM-стратегія; цінність для клієнта; клієнтський досвід; омніканальна взаємодія; шлях клієнта; управління даними; Big Data; аналітика даних; штучний інтелект; цифрові платформи; стратегічне управління; організаційна культура; цифрові компетентності; клієнтоорієнтованість; сталий розвиток

Introduction. In the modern conditions of the digital economy, customer relationship management acquires a qualitatively new meaning, which is due to the transformation of consumer behavior, increased competition and the rapid development of digital technologies. Customers increasingly expect personalized solutions, prompt response and seamless interaction through various communication channels, which significantly increases the requirements for customer relationship management systems and the logic of their development [1-3].

The relevance of the above-mentioned issues is confirmed by the results of international expert assessments and applied research. Thus, according to a survey by Accenture Digital [4] conducted among more than 13 thousand consumers, two thirds of customers change their service provider in case of unsatisfactory quality of service. Gartner [5] analysts note that about 90% of companies in the service sector compete primarily on the quality of customer interaction, while Salesforce [6] research shows that 76% of consumers expect companies to have a deep understanding of their individual needs and a personalized approach to communication.

Consulting and analytical reports also indicate the strategic nature of the digital transformation of customer processes. According to the results of a survey by IDG Communications [7], digital transformation is considered by management in 46% of cases

as a tool for improving the quality of customer service. Altimeter-Prophet [8] research showed that more than half of experts associate digital changes primarily with improving the system of contacts with consumers. At the same time, Econsultancy [9] experts emphasize that only 58% of companies integrate customer orientation into their digital strategies, while the majority is limited to the implementation of individual technological solutions.

An important argument in favor of a strategic approach is the economic effect of developing customer relationships. According to Bain & Company [10], up to 65% of companies' revenues are generated by existing customers, and increasing loyalty by even 5% can provide a significant increase in profitability. PwC studies [11] show that companies that invest in the digital transformation of customer processes demonstrate higher revenue growth rates compared to competitors focused exclusively on operational efficiency. At the same time, the practice of operating companies shows that the implementation of CRM systems and digital tools is often fragmentary and is not accompanied by the formation of a holistic digital transformation strategy. In such conditions, CRM is reduced to a technical platform for automating interaction with customers and does not perform the function of a strategic management tool [12]. This necessitates the transition from an instrumental approach to developing a strategy for the digital transformation of a

customer relationship management system that can provide long-term competitive advantage and sustainability of the business model.

Literature and researches review. In the scientific literature, the issue of customer relationship management is formed within the framework of an interdisciplinary discourse that combines marketing, strategic management, logistics and behavioral economics. Initial studies considered CRM mainly as a tool for supporting sales activities and automating customer contacts. In the works of P. Kotler, K. Keller [1], C. Grönroos [2], J.-J. Lambin [13], the emphasis is on the formation of long-term value relationships with consumers as a key condition for increasing the competitiveness of enterprises. The further evolution of approaches is associated with the transition to strategic management of customer assets. In particular, A. Payne and P. Frow [3] interpret CRM as an integrated system of strategic processes aimed at creating mutual value for customers and the company. A similar logic is traced in the works of R. Kumar, V. Reinartz [14], where customer relationship management is associated with customer lifecycle management and maximizing its long-term value.

With the development of digital technologies, CRM research is increasingly focused on the use of data, analytics, and intelligent algorithms. The works of T. Davenport, J. Harris [12] emphasize that analytics and data-driven approaches expand the possibilities of personalizing customer interactions, but do not replace the need for strategic integration of digital solutions into the management system. This led to the formation of the digital CRM direction, within which the role of omnichannel communications, platform solutions, and big data is analyzed [15].

In recent years, research has intensified on the impact of artificial intelligence on customer relationship management. The works of M. Ngai, E. Hu, Y. Wong [16] show the potential of machine learning for predicting

customer behavior and improving service quality. At the same time, bibliometric reviews show that most publications focus on the technological aspects of CRM, while the issues of strategic transformation of the customer relationship management system remain insufficiently systematized [17].

A separate area of research is related to the concepts of customer and digital customer experience. In the works of B. Schmitt, K. Lemon, P. Verhoef [19] CRM is considered as an infrastructural basis for customer experience management, covering all points of customer interaction with the company. At the same time, in studies of digital business transformation (D. Rogers [20], G. Westerman et al. [21]) CRM is usually considered as a functional element of the overall transformation, and not as an independent object of strategic management.

Thus, the analysis of scientific publications indicates the evolution of approaches to CRM from instrumental models to customer-oriented and digitally enhanced concepts. At the same time, the strategic dimension of the digital transformation of the customer relationship management system remains insufficiently disclosed, which forms a scientific gap and justifies the feasibility of further research in this direction.

Aim and objectives. The outlined problem determined the purpose of this article, which is to substantiate and develop a strategy for the digital transformation of the customer relationship management system as a holistic management concept that ensures the integration of digital technologies, customer-oriented processes and data management in the context of long-term development of enterprises.

Achieving the set goal involves solving a set of interrelated scientific tasks that logically follow from the chosen subject of research. In particular, the work summarizes modern scientific approaches to the interpretation of customer relationship management and digital transformation of business processes; justifies the feasibility of the transition from

instrumental use of CRM to strategic customer relationship management; formulates the author's interpretation of the strategy for the digital transformation of the customer relationship management system; develops a structural and logical model of the specified strategy; identifies key areas and practical recommendations for its implementation in the activities of enterprises, taking into account modern digital challenges [3; 12; 20].

The methodological basis of the study is a set of general scientific and special methods of cognition, the application of which ensures the comprehensive and systemic nature of the results obtained. In the process of the study, a systemic approach was used to consider the customer relationship management system as a multi-level dynamic system that is transformed under the influence of digital technologies and changes in the external environment. Methods of analysis and synthesis were used to generalize scientific approaches and identify key elements of the digital transformation of CRM, while induction and deduction allowed the formation of author's generalizations and theoretical conclusions [2; 15].

To identify the dominant scientific trends and evolution of research in the field of customer relationship management, methods of comparative analysis and generalization of the results of modern scientific publications were used. Structural and logical modeling was used to build an author's model of the strategy for the digital transformation of the customer relationship management system, which reflects the relationship between strategic, organizational, technological and customer-oriented components. Elements of expert analysis were used to interpret practical aspects of CRM digital transformation and formulate applied recommendations for management practice [16; 19].

The information base of the study consists of scientific publications of foreign and domestic scientists, analytical reports of international consulting companies, results of

expert surveys and research, as well as materials of open professional and scientific sources.

The use of the specified methodological tools allowed to ensure the validity of the obtained results, their scientific novelty and practical significance in the context of developing a strategy for digital transformation of the customer relationship management system.

Results, analysis, and discussion. In the digital era, the customer relationship management system ceases to be a set of isolated information solutions and is transformed into a multi-level managerial system integrated with the corporate development strategy of the enterprise. In this context, the digital transformation of CRM should be considered not as a technological project but as a long-term strategy of organizational, process-related, and behavioral change aimed at creating customer value and enhancing the resilience of the business model.

The analysis of contemporary scientific and applied approaches indicates that most enterprises focus on the implementation of digital tools for customer interaction while neglecting the strategic coherence of such solutions. As a result, digital initiatives in the field of CRM are often fragmented, insufficiently integrated into the managerial decision-making system, and unable to deliver long-term effects. Therefore, the digital transformation strategy of the customer relationship management system should be based on a systemic vision of CRM as a key element of managing the enterprise's customer capital.

Taking this into account, the article proposes an author's interpretation of the digital transformation strategy of the customer relationship management system, which is defined as an integrated managerial concept of the long-term development of CRM that involves the alignment of digital technologies, customer-oriented business processes, data management, and organizational change in order to ensure

personalized customer interaction, increase customer loyalty, and create sustainable competitive advantages for the enterprise.

Unlike traditional approaches, the proposed strategy is oriented not toward the automation of individual functions but toward transforming the entire logic of customer relationship management. It implies a transition from a reactive model of customer interaction to a proactive and predictive-analytical one based on the use of Big Data, intelligent analytics, and digital communication channels. In this context, CRM acts not only as an information platform but also as an institutional foundation for managerial decision-making.

The digital transformation strategy of CRM has a multidimensional nature and is implemented through the alignment of the enterprise's strategic goals with the customer strategy, organizational structure, digital infrastructure, and management culture. Its implementation involves the creation of a unified information space for customer interaction, the integration of data from multiple channels, ensuring transparency of customer-related processes, and establishing feedback mechanisms that allow managerial decisions to be promptly adapted to changes in consumer behavior.

An important component of the proposed strategy is the reconsideration of the role of customer experience in the customer relationship management system. Within the framework of digital transformation, customer experience is interpreted as the result of coordinated interaction among technological, process-related, and behavioral components rather than as a side effect of individual customer contacts. This implies that the digital transformation strategy of CRM should encompass all customer touchpoints and ensure their consistency and integrity.

The implementation of the digital transformation strategy of the customer relationship management system also requires the transformation of organizational and managerial practices. This includes changes in approaches to planning, monitoring, and evaluating customer-related performance, as well as the development of new personnel competencies in the fields of data handling, digital tools, and customer analytics. Without appropriate institutional support and employee engagement, the digital transformation of CRM risks remaining merely formal.

Thus, the digital transformation strategy of the customer relationship management system should be considered a comprehensive process that combines technological, organizational, and managerial changes and enables the transition to a customer-oriented, data-driven, and sustainable enterprise development model in the digital economy.

Accordingly, the proposed digital transformation strategy of the customer relationship management system is implemented as a multi-level managerial framework that integrates the strategic development priorities of the enterprise with operational mechanisms of customer interaction and analytical support for managerial decision-making. This approach makes it possible to avoid the fragmentation of digital initiatives and to ensure coherence between digital transformation objectives, organizational structure, business processes, and customer experience.

In this context, it is appropriate to distinguish the levels of implementation of the CRM digital transformation strategy, each of which performs a specific function while simultaneously forming part of a unified strategic framework (Table 1).

Table 1. Levels and Key Components of the Digital Transformation Strategy of the Customer Relationship Management System

Level	Content of Strategic Decisions	Key Components
Strategic	Formation of a customer-oriented vision of enterprise development and determination of the role of CRM in achieving long-term goals	Customer strategy; digital vision; value proposition
Managerial	Alignment of CRM with the corporate governance system and decision-making mechanisms	Customer management policies; KPIs; customer value management
Process	Transformation of customer interaction business processes based on digital solutions	Omnichannel processes; customer journey; channel integration
Technological	Provision of digital infrastructure for the implementation of the CRM strategy	CRM platforms; data analytics; artificial intelligence
Analytical	Development of data-driven management of customer relationships	Big Data; predictive analytics; personalization
Behavioral	Formation of a customer-oriented culture and digital competencies of personnel	Training; employee engagement; transformation of managerial practices

Source: developed by the authors based on analysis and generalization of [1; 2; 14; 20; 21; 22-27].

The identified levels are not isolated but operate in close interconnection, forming an integrated architecture of the CRM digital transformation strategy. The implementation of such a strategy implies a sequential transition from shaping a strategic vision to deploying specific digital solutions and transforming managerial practices. In this regard, it is appropriate to consider the stages of development and implementation of the digital transformation strategy of the customer relationship management system (Table 2).

The logic of phased implementation makes it possible to interpret the digital transformation of CRM as a continuous adaptive process rather than a one-time automation project. At this stage, the strategy moves from a declarative level to practical implementation and becomes an effective instrument for managing customer value.

To summarize the presented provisions and to visualize the interrelationships among key elements, it is appropriate to present a structural-logical model of the digital transformation strategy of the customer relationship management system (Figure).

Table 2. Stages of Development and Implementation of the CRM Digital Transformation Strategy

Stage	Content	Expected Results
Diagnostic	Assessment of CRM maturity, digital competencies, and customer-related processes	Identification of strategic gaps and growth points
Conceptual	Formulation of goals and principles of CRM digital transformation	Aligned strategic vision
Design	Development of a roadmap for digital transformation	Clear logic of change implementation
Implementation	Deployment of digital solutions and transformation of processes	Integrated customer management system
Analytical-Adaptive	Monitoring of results and strategy adjustment	Increased efficiency and adaptability

Source: developed by the authors based on analysis and generalization of [3; 12; 14; 18; 19; 22-27].

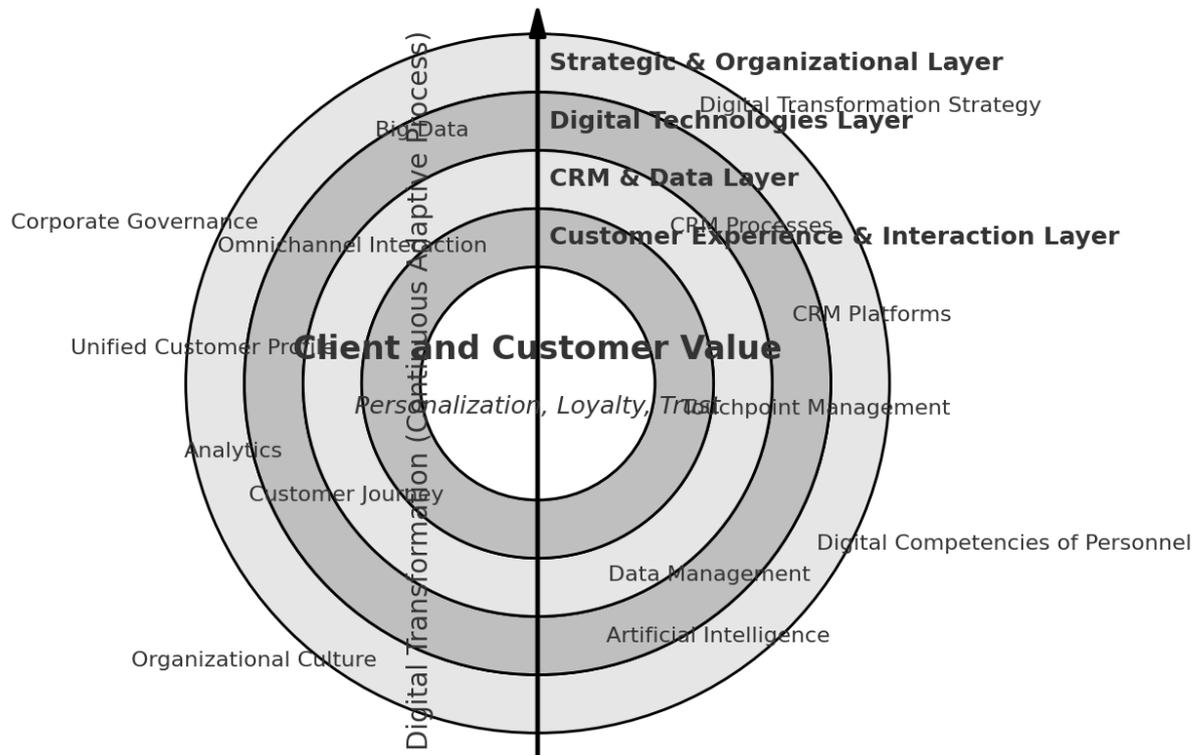


Figure 1 – Structural-Logical Model of the Digital Transformation Strategy of Customer Relationship Management System

Source: developed by the authors based on the results of their own previous research [22-27], using Artificial Intelligence tools.

The proposed figure visualizes a structural–logical model of the digital transformation strategy of the customer relationship management (CRM) system and is based on the principle of concentric levels supplemented by a vertical axis representing digital transformation as a continuous process. Such a configuration makes it possible to demonstrate that CRM digital transformation is not limited to the implementation of a software product but constitutes a coordinated architecture of strategic, organizational, process-related, and technological changes oriented toward the creation and reproduction of customer value.

At the center of the model is the customer and customer value as the key object of management. This implies that the

CRM digital transformation strategy should be derived not from the internal logic of automation but from the logic of the value proposition and the target effects for the customer. The specifying attributes of the core (personalization, loyalty, trust) indicate that the outcome of transformation should not be a “digitized contact” but the sustainable reproduction of behavioral and relational effects, such as customer retention, repeat purchases, recommendations, reduced price sensitivity, and tolerance for service failures. Thus, the core of the model defines the criterion for the overall effectiveness of the strategy, namely the system’s ability to increase the long-term value of the customer and for the customer.

The second concentric level forms the customer experience and interaction layer. Its immediate proximity to the core emphasizes that customers "encounter" the enterprise primarily through their experience at touchpoints; therefore, CRM management in the digital economy should begin with the design and alignment of the customer journey and omnichannel communication. Within this layer, three interrelated components are distinguished: omnichannel interaction, which ensures channel consistency, a unified service logic, and continuity of communication regardless of the channel; the customer journey as the logic of sequential customer steps (need → search → choice → purchase → use → support → repeat decision); and touchpoint management as a mechanism for ensuring service quality, speed, accessibility, personalization, and unified service standards. Consequently, this layer functions as an "interface" between the customer and the enterprise while simultaneously defining the requirements for processes, data, and technologies at subsequent levels.

The third level is process-analytical and demonstrates a fundamental idea: CRM is primarily a system of processes and data rather than merely a software product. This level comprises three basic pillars of manageability: CRM processes (customer acquisition, conversion, service, retention, reactivation, customer development, complaint handling, etc.); a unified customer profile resulting from the integration of data from all channels, departments, and interaction points (sales, service, logistics, marketing, support); and data management (quality, timeliness, completeness, accessibility, access rules, security, and compliance), which ensures the reliability of analytics and personalization. The logic of this layer lies in the fact that CRM digital transformation will be effective only when data and processes form a single manageable system in which interactions are not duplicated across departments, decisions are based on a single version of the data, and

customers perceive the company as an integrated entity rather than a set of fragmented contacts.

The fourth level reflects the technological foundation of digital transformation, including CRM platforms, Big Data, analytics, and artificial intelligence tools. Its position above the process-and-data core emphasizes that technologies should support processes and data rather than "replace" strategy. The functional role of this layer is to enable personalization (recommendation systems, segmentation, next best action/offer, personalized communication scenarios), forecasting (churn probability, customer lifetime value prediction, demand forecasting, communication response), automation (triggers, scenarios, chatbots, robotic assistants, automated task creation and lead management), and analytical support for management (dashboards, channel performance analytics, CX/CSAT/NPS measurement, attribution, etc.). Accordingly, digital technologies are interpreted in the model as an instrumental base for achieving objectives defined at the level of customer value and customer experience.

The outer level forms the governing framework that ensures the sustainability of transformation in the long term. This level includes the digital transformation strategy (goals, priorities, roadmap, initiative portfolio, metrics), corporate governance (responsibility allocation, product and data ownership, decision-making rules, change management), organizational culture (customer centricity, data culture, cross-functional interaction, readiness for experimentation), and digital competencies of personnel (analytics, CRM usage, service design, cyber hygiene, product and process management). It is precisely this framework that transforms digital transformation from a one-time IT project into an organizational capability for continuous adaptation, process renewal, experience enhancement, and scaling of data-driven solutions.

The vertical arrow intersecting all levels highlights that CRM digital transformation is

an end-to-end process integrating all elements of the model. It reflects the logic of a "continuous improvement cycle": strategic alignment → redesign of interactions and processes → data development → technological enhancement → measurement of effects → adjustment and scaling. Thus, the strategy does not end with the implementation of a CRM platform but continues through the monitoring of customer value indicators, experience quality, and process efficiency.

Overall, the figure demonstrates that the CRM digital transformation strategy integrates behavioral (value/loyalty/trust), process-related (customer journey/CRM processes), data-oriented (unified profile/data management), technological (AI/analytics/platforms), and organizational-managerial (strategy/culture/competencies) dimensions into a single coherent managerial architecture.

Conclusions. As a result of the conducted research, it has been established that in the context of the digital economy the customer relationship management system undergoes profound transformation that goes beyond the automation of individual functions and acquires a strategic nature. The digital transformation of CRM is increasingly determined not by the mere implementation of technological solutions but by the ability of enterprises to integrate customer value, customer experience, business processes, data, digital technologies, and organizational change into a single manageable system. The effectiveness of a customer-oriented development model and business resilience under conditions of intensifying competition and changing consumer behavior largely depend on the coherence of these elements.

The scientific novelty of the obtained results lies in the improvement of the scientific and methodological approach to shaping a digital transformation strategy for the customer relationship management system, which is based on interpreting CRM as an integrated managerial architecture rather than as a standalone tool or information

platform. The understanding of CRM digital transformation as a continuous adaptive process encompassing strategic, process-related, technological, and behavioral dimensions of management has been further developed. For the first time, a structural-logical model of the CRM digital transformation strategy has been proposed, built on the principle of concentric levels with a vertical integrating axis, which makes it possible to formalize the interrelationships between customer value, customer experience, the process-and-data core of CRM, digital technologies, and the strategic and organizational management framework.

The obtained results have significant practical value and can be applied by various stakeholder groups. For top management and business owners, the proposed strategy provides a methodological basis for transitioning from fragmented digital initiatives to an integrated customer-oriented development model, in which CRM serves as a tool for managing customer capital and a source of long-term competitive advantages. The use of the structural-logical model enables the alignment of enterprise strategic objectives with the customer strategy, the formation of a portfolio of digital initiatives, and the assessment of their effectiveness through indicators of customer value and customer experience quality.

For heads of functional units, including marketing, sales, service, and logistics, the research results provide a foundation for redesigning customer interaction business processes based on a unified customer journey logic and omnichannel interaction. The proposed process-and-data-oriented approach to CRM helps eliminate functional duplication, increase transparency of customer-related processes, and form a unified customer profile, which in turn creates prerequisites for service personalization and improves the effectiveness of managerial decision-making.

For IT departments and digital transformation specialists, the results of the study make it possible to reconsider the role

of digital technologies in CRM as instruments for supporting strategic and process-related changes. The proposed model emphasizes the necessity of combining CRM platforms, Big Data analytics, and artificial intelligence tools with clearly defined managerial objectives, data governance rules, and mechanisms of cross-functional integration. This reduces the risks of technological redundancy and increases the return on investment in digital solutions.

For enterprise personnel and specialists involved in customer interaction, the practical significance of the research lies in substantiating the role of organizational culture and digital competencies as critically important factors for the success of CRM digital transformation. The implementation of the strategy proposed in the article involves fostering a culture of customer orientation,

data-driven thinking, and cross-functional collaboration, which contributes to higher employee engagement and improved quality of customer service.

Prospects for further research are associated with the deepening of methods for the quantitative assessment of the effectiveness of CRM digital transformation strategies, particularly through the development of indicator systems for measuring customer value, customer experience, and the economic outcomes of digital change. Of particular scientific interest is the empirical testing of the proposed structural–logical model using data from enterprises of different industries and scales of activity, as well as the analysis of the impact of artificial intelligence tools on customer relationship management under conditions of high uncertainty.

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