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e-mail: support@smart-scm.org
тел.: (063) 593-30-41
https://smart-scm.org

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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 discus and debate on them, to work together to develop the scientific theory of logistics and promote mutual intellectual enrichment.

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

HRYHORAK Mariia
Chief Editor

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Hryhorak M. Yu. Doctor of Sciences (Economics), Professor (Associate), Academician of the Academy of Economic Sciences of Ukraine, Professor of Department of International Business and Logistics of National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0002-5023-8602
Researcher ID – AAK-2963-2021
Scopus author id: – 57208222758
E-Mail: hryhorak.mariia@lll.kpi.ua

EVOLUTION OF LOGISTICS DEFINITIONS AND CONCEPTS: BETWEEN FUNCTIONALITY, INTEGRATION AND GLOBALITY

Mariia Hryhorak. «Evolution of logistics definitions and concepts: between functionality, integration and globality». *This article explores the evolution of logistics from a narrow functional activity focused on the movement of material flows to a comprehensive interdisciplinary science that addresses the management of diverse flows -material, informational, financial, and human - within and across economic systems. The study highlights the need to update the conceptual and terminological framework of logistics in response to the challenges of digital transformation, sustainable development, and the growing role of human and social dimensions in logistics. The authors propose a revised definition of logistics that reflects its scientific essence, strategic nature, and societal value. A structured model of logistics as a science is developed, including its object of study, hypotheses, laws, principles, and methodological approaches. The paper identifies five stages of the historical development of logistics concepts and categorizes them into traditional, SCM-oriented, and digitally- and sustainability-driven concepts. It is argued that logistics not only integrates knowledge from economics, management, informatics, cybernetics, and social sciences, but is also increasingly capable of contributing its own scientific tools and approaches to these fields. Future research directions are outlined, including the development of logistics for virtual systems, the expansion of humanitarian-oriented practices, and the growing application of logistics in crisis and recovery contexts.*

Keywords: Logistics as a science, flow management, logistics systems, supply chain concepts, digital transformation, human-centric logistics, interdisciplinary approach, logistics methodology

Марія Григорак. «Еволюція визначень і концепцій логістики: між функціональністю, інтеграцією та глобальністю». *У статті досліджено логістику як самостійну міждисциплінарну наукову галузь, що еволюціонувала від функціональної сфери управління матеріальними потоками до системного підходу до управління потоками різної природи: матеріальними, інформаційними, фінансовими та людськими. Обґрунтовано актуальність оновлення понятійно-категоріального апарату логістики з урахуванням викликів цифрової трансформації, сталого розвитку, гуманітаризації управлінських практик та розвитку логістики 5.0. Запропоновано авторське* *визначення логістики, яке узгоджується з сучасними вимогами до системності, інтегрованості, стратегічного бачення та соціальної орієнтації логістичної діяльності. Представлено структурну модель логістики як науки, що включає об'єкт, гіпотези, закони, принципи та методологічні підходи. Визначено етапи еволюції логістичних концепцій, виокремлено традиційні, SCM-орієнтовані та сучасні цифрово-орієнтовані концепції. Обґрунтовано, що логістика не лише інтегрує знання з економіки, менеджменту, інформатики, кібернетики та соціальних наук, але й починає формувати власний науковий інструментарій, придатний до зворотного перенесення в інші наукові дисципліни. Встановлено перспективи подальших досліджень у напрямі формування логістики віртуальних систем, посилення гуманітарного виміру логістичних практик та розширення прикладного потенціалу логістики в кризових і посткризових умовах.*

Ключові слова: логістика як наука, управління потоками, логістичні системи, концепції ланцюгів постачання, цифрова трансформація, людиноцентрична логістика, міждисциплінарний підхід, методологія логістики.

Intraduction. Over the past few decades, the concept of logistics has undergone significant transformations, reflecting the evolution of its role in socio-economic systems at various levels. From the initial understanding of logistics as a purely operational function that ensures the movement of material resources, this field has gradually evolved into an interdisciplinary, strategically important tool for managing flows within and beyond organizations. This transformation is driven by a complex set of factors, among which the globalization of the economy, the dynamic development of information and communication technologies, intensified competition, increasing complexity of supply chains, and the growing importance of sustainable development principles play a key role.

The relevance of the study is due to a noticeable gap between the theoretical understanding of logistics, as presented in academic and scientific literature, and its practical application in the real business sector. In the national educational practice, logistics is often presented as a tool for managing material flows or as a functional discipline within economic science. In contrast, the logistics business – especially in the fields of transport, warehousing, distribution, and outsourcing – operates with a practical understanding of logistics as a complex of processes related to movement, storage, customer service, and ensuring the continuity of supply chains.

The increasing importance of logistics in the context of globalization, Ukraine's integration into global logistics networks, the development of transport infrastructure, and the formation of the state's ambitions as a potential logistics hub of the Black Sea-Baltic region reinforce the need to review the theoretical foundations of logistics. An interdisciplinary approach becomes particularly relevant, allowing logistics to be understood not only as an applied economic function but as a scientific category that integrates economics, management, informatics, engineering, and social sciences.

An analysis of academic and scientific literature shows that most definitions of logistics boil down to managing material, information, and financial flows to increase the efficiency of economic entities. In particular, one of the leading Ukrainian researchers, Y.V. Krykavsky, considers logistics as a branch of economic science that studies flow management in adaptive economic systems with synergistic connections [1, c.199]. In subsequent works, he identifies three approaches to defining logistics: focused on movement (transformation of resources in space and time), focused on the product life cycle, and focused on providing logistics services [2, c.6]. Similar interpretations are present in the works of other authors who emphasize logistics as a tool for optimizing supply, distribution, inventory, and internal flows [3, 4, 5, 6].

Despite the variety of approaches, most of them do not take into account new contexts of logistics functioning – in particular, its impact on the environment, the social sphere, digital transformation, global integration, and its humanitarian role in crisis situations. As a result, there is a need to formulate an updated scientific vision of logistics as a systemic, interdisciplinary, and dynamic science of flow management.

Thus, the formation of a modern methodological basis for logistics requires not only a rethinking of its basic definitions but also a deeper understanding of its evolution, strategic function in socio-economic systems, and integrative potential with other scientific disciplines.

Literature review. The establishment of logistics as an integrated, strategic, and global discipline has been accompanied not only by changes in practical application but also by a revision of theoretical approaches to its essence, functional tasks, and key concepts. Historical analysis of scientific sources indicates a gradual transition from narrow functional interpretations of logistics to a systemic, inter-functional, and strategic understanding of it.

It should be noted that the evolution of logistics as a theoretical category and an applied discipline is the subject of research by numerous national and foreign scientists. Modern scientific literature reflects the complex and multifaceted nature of logistics transformation, which necessitates the systematization of approaches to its interpretation at various stages of development.

One of the first formalized approaches to defining logistics is considered to be the concept formulated in the military sphere, where logistics was seen as an activity for providing troops with material resources, their transportation, and storage [7]. For centuries, military logistics developed in two dimensions: as an art and as a science, applying, according to its nature, various historically proven concepts that were useful for supporting armies. The most complete analysis of the evolution of military logistics is the work [8], whose authors proposed the concept of target logistics, defining it as a science that continuously studies, plans, manages, and systematically executes the process of timely supply of necessary resources for the functioning of armed forces in war zones, using available technologies and means to dynamically facilitate the development of operations and maneuverability of units.

In commercial practice until the middle of the 20th century, logistics was understood primarily as a set of operations for transportation, warehousing, and inventory management, which corresponded to the concept of physical distribution [9]. This approach was fragmented and mostly operational. During the same period in the military sphere, logistics was already acquiring a strategic character, being considered as integrated management of resource provision for troops, which involved the coordination of supply, transport, accounting, and storage. It was military logistics that laid the foundation for the further transformation of commercial logistics [10, 11].

From the 1970s, under the influence of information technology development, globalization, and the increasing complexity of the market environment, a systemic vision of logistics as an integrated activity began to form. In the works of leading researchers, including D. Bowersox, D. Closs, J.R. Stock, D.M. Lambert, logistics is considered as an inter-functional system that combines the processes of supply, production, sales, financial services, and information support [12, 13, 14]. This approach allowed for a shift from individual operations to the management of logistics systems and networks.

In the second half of the 1990s, a formal conceptual distinction between logistics and Supply Chain Management (SCM) was observed. SCM encompasses a broader range of tasks, including strategic planning, coordination of all supply chain participants – from raw material suppliers to end consumers, integration of business processes, building partnerships, and synchronization of flows at an inter-organizational level [15]. Authors such as M. Christopher, L. Mentzer, R. Ballou emphasize that logistics is a component of SCM, focused on the execution and optimization of physical flows, while SCM also covers strategic interaction and value-added management throughout the entire chain [16, 17, 18]. Investigating the evolution of logistics from physical distribution to supply chain management, the authors [19] concluded that material flow theory is an option for solving the problem of the extreme complexity of material flow systems in the global economy of the twenty-first century.

From the beginning of the 21st century, the scientific community began to realize that logistics – as a discipline concerned with the management of material, information, financial, and resource flows – has not only economic but also significant environmental and social consequences. The increase in global flows, the intensification of transport activities, and the expansion of logistics networks have led to increased energy consumption, greenhouse gas emissions, and waste generation, which, in turn, became the subject of critical analysis by researchers. One of the first significant steps in this direction was the formation of the "green logistics" concept, which focuses on minimizing the negative impact of logistics processes on the environment [20, 21]. Researchers such as J. Rodrigue [22], Alan McKinnon [23, 24] and Joseph Sarkis [25], played a key role in popularizing the idea that environmental efficiency should be as important as economic efficiency.

During the same period, the theory of Sustainable Supply Chain Management began to form. Important stages in its development were the works of Seuring & Müller [26], who proposed an integrative framework for researching the sustainable supply chain, covering three key dimensions: economic, environmental, and social. Their article in the Journal of Cleaner Production became a foundational document for further research in this field. Other scientists drew attention to ethical issues, labor conditions, and community impact, which spurred the inclusion of the social dimension of sustainability in logistics research [27, 28]. Furthermore, the introduction of the "Circular Economy" concept into logistics increased interest in reverse logistics, recycling, reuse, and extending the life cycle of goods [29, 30].

Thus, the beginning of the 21st century marked a significant shift in the paradigm of logistics research – from focusing solely on efficiency to seeking balanced solutions that consider the interests of the environment, society, and business. This necessitated the development of new models, principles, and approaches that form the scientific basis of sustainability in logistics and supply chain management.

A separate area of research is related to the impact of digital technologies on the development of logistics. Modern concepts, including Logistics 4.0, Smart Logistics, and Digital Logistics, have emerged as a response to the growing complexity of logistics networks, the need to process large volumes of data in real-time, and the integration of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, blockchain, and so on. One of the pioneers in the development of digital logistics theory is E. Hofmann in co-authorship with M. Rüsch. In their article "Industry 4.0 and the current status as well as future prospects on logistics" (2017), they formalized the concept of "Logistics 4.0" as the integration of cyber-physical systems, IoT, and cloud solutions into logistics networks and emphasized a turning point: logistics became not just an operational function, but a system of smart, interconnected, and automated flows [31]. No less influential is the contribution of J. Sarkis, who analyzes digital logistics in the context of sustainable development, emphasizing the role of data analytics and AI in decision-making aimed at efficiency and environmental responsibility [32]. The focus of modern research is the integration of digital technologies into logistics processes – from mobile sensors and warehouse automation to autonomous vehicles, blockchain, and digital twins, which opens up new functions of logistics – not only planning the movement of goods but also managing data, forecasting, and real-time analysis [34, 35]. Modern logistics goes beyond transportation and warehousing and encompasses managing data flows, demand forecasting, real-time resource management, adaptive planning, and modeling complex scenarios. Data analytics becomes a central element of decision-making in logistics, allowing for a higher level of accuracy, speed, and flexibility [36]. Furthermore, digital logistics is closely integrated with ERP systems, SCM platforms, and CRM, forming a unified information environment for enterprise management [37]. This integration ensures the transparency of logistics processes, improves control, and creates a basis for implementing sustainable development concepts, as it allows for precisely tracking the impact of logistics solutions on environmental, economic, and social aspects.

Thus, the development of digital technologies transforms logistics from an operational function into a strategic, interdisciplinary, and technologically intelligent field of activity that is at the heart of modern supply chain management and plays an important role in achieving sustainable development.

This brief overview of literary sources demonstrates that approaches to defining and conceptualizing logistics have changed significantly over the past decades. Initially, logistics was perceived as a purely operational function focused on the physical movement of goods and inventory management. However, with the development of the economy, the complication of production and trade links, the introduction of information technologies, and the formation of global supply chains, logistics gradually transformed into an inter-functional, interdisciplinary, and strategic tool for managing flow processes.

Modern scientific approaches view logistics not only as a practical activity but as a scientific discipline with its own methodology, object, and subject of research. Accordingly, the definitions of logistics are also changing, increasingly emphasizing not only material flows but also information, financial, and human resources, as well as the need to ensure the sustainability, flexibility, and value orientation of logistics solutions.

It is important to emphasize that such a re-evaluation of the scientific foundations of logistics has already taken place at the level of authoritative international organizations. For example, after the Council of Supply Chain Management Professionals (CSCMP) clearly distinguished logistics as a separate discipline from supply chain management, other professional associations, including the European Logistics Association (ELA) and the German Logistics Association (BVL), also revised their interpretations of logistics, including a wider range of processes, levels, and goals. Of particular interest to our research were publications by the working group of the Scientific Advisory Board of the German Logistics Association (BVL), which emphasized the need to design flows in logistics networks and proposed a definition of logistics that reflects the balanced achievement of economic, environmental, and social goals [38]. It is worth noting the conclusion of B. Fisher-Holloway and M. Mokhele that, as a science, logistics should integrate more theoretical (including non-obvious) approaches from other disciplines to strengthen its own theoretical foundation. This particularly refers to human geography, which studies the human spatial behavior, mobility, and the spatial differentiation of economic activity [39].

Thus, in the conditions of profound transformations in the socio-economic environment, digitalization, globalization, and the challenges of sustainable development, there is an objective need to update the general theory of logistics as a science that must respond to new demands of practice and scientific knowledge.

Aim and Objectives of the Study. The aim of this work is to systematize the stages of logistics' evolution as a scientific discipline, substantiate the changes in its conceptual content, object, and subject of research in the context of the development of logistics concepts, and to refine the methodological foundations of logistics in accordance with contemporary challenges of digital transformation, sustainable development, and the humanization of logistics practices. To achieve this aim, the following objectives have been formulated:

1. To compare definitions of logistics by various authoritative organizations (CSCMP, ELA, and BVL) and propose an original definition that encompasses current trends in its development.
2. To define the logical structure of scientific inquiry in logistics through the sequence: hypotheses → laws → principles → methodology.
3. To analyze the development of logistics concepts and strategies in relation to transformations in the economic, technological, and social environment.
4. To refine the methodology of logistics as an interdisciplinary science that combines knowledge from various fields and is capable of modeling complex virtual systems.

Methodology for writing this article is based on a combination of theoretical-analytical and conceptual approaches, which allows for examining logistics as a scientific discipline in its evolution, content, structure, and contemporary transformations. The choice of methodology is determined by the research aim – to conduct a critical analysis of existing definitions of logistics, to comprehend its object of study, principles, laws, methodological foundations, and to present an original interpretation of logistics that meets the current challenges of digitalization, sustainable development, and humanization. The following methods were used in the research process:

– Systemic approach that allowed for considering logistics as a holistic system of knowledge, including concepts, principles, methods and areas of application. This approach enabled the identification of interconnections between flows of various natures (material, informational, financial, and human) and reflected the complex multi-level structure of logistics systems.

– Comparative-analytical method applied to compare the author's definition of logistics with definitions used by leading international organizations (CSCMP, ELA, BVL), with the aim of identifying common and distinctive features, strengths, and limitations.

– Historical-logical method allowed for a stage-by-stage analysis of the development of logistics concepts – from its inception as an applied field to its modern interdisciplinary and strategic approach. Within this method, the periodization of logistics development and its concepts was substantiated.

– Elements of an axiological approach used to account for the social, humanitarian, and environmental value of logistics in the context of its evolution from an operational function to a tool for sustainable management.

– Conceptual modeling method applied to construct a generalized systemic model of logistics development as a science, in which definitions, hypotheses, laws, principles, approaches, and methodology are considered in their interrelationship.

Since the article's aim is not purely empirical, the main source is analytical work with scientific publications, international standards, programmatic documents, and logistics practices, which allowed for generalizing current knowledge, formulating an original conceptual framework, and outlining directions for further research.

Main Text. The current stage of economic and business environment development is accompanied by a growing volume of theoretical knowledge and practical experience in the field of enterprise logistics and supply chain management. This applies to both traditional aspects of logistics related to the management of material flows, information, finance, and human resources, as well as the latest trends in the transformation of logistics activities under the influence of digital technologies, sustainable development concepts, process intellectualization, and corporate social responsibility.

Over the past decades, logistics has gradually moved beyond being solely an applied function of operational flow management and has transformed into a complex, interdisciplinary field that requires not only practical solutions but also a thorough theoretical understanding. The expansion of logistics concepts' application areas, particularly in public administration, the humanitarian sphere, security, tourism, and human flow management, indicates the growing societal importance of logistics and its gradual integration into broader socio-economic systems.

In accordance with the classical understanding of science as a systematized, structured body of knowledge about the world, obtained as a result of scientific research, observations, experiments, and analysis of facts, the accumulated theoretical and empirical material in the field of logistics forms the objective prerequisites for its further establishment and development as an independent, interdisciplinary scientific field. In view of this, it is appropriate not only to analyze existing theoretical approaches but also to formulate an original vision of logistics as a theory and practice at the current stage of its evolution, taking into account new technological, economic, and social challenges.

Modern logistics has long transcended a narrow operational understanding that limited it to managing transport, warehousing, or inventory. The accumulated scientific and practical experience, the digitalization of economic processes, the increasing complexity of global supply chains, growing social expectations for business, and the integration of sustainable development principles necessitate viewing logistics as a comprehensive, interdisciplinary field that combines both applied and scientific components. In this regard, we propose the following definition: "Logistics is an interdisciplinary applied scientific and practical activity that investigates, models, plans, organizes, implements, and controls flows of material resources, information, finances, people, and related services in space and time within and between economic systems and networks, with the aim of effectively creating value for business and society, ensuring competitiveness, achieving a balanced fulfillment of economic, social, and environmental goals, and fostering harmonious interaction between people, technology, and the environment".

Comparison allows us to assess how our definition aligns with current scientific standards, identify its strengths and potential weaknesses, and highlight the specifics and unique aspects of our approach. The following definitions of logistics were taken as a basis:

– ***CSCMP***: the process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal, and external movements [40];

– ***ELA***: the implementation, plan and control of transportation and arrangement of goods and personal and the corresponding support tasks in a system to attain specific need [41];

– ***BVL***: an applications-oriented scientific discipline. It models and analyses economic systems as networks and flows of objects through time and space (specifically goods, information, money, and people) which create value for people. It aims to supply recommendations for action on the design, implementation, and mobilization of such networks and flows through accepted scientific methods [42].

The results of the comparative analysis of the proposed author's definition with the definitions of recognized leaders in the field of logistics and supply chain management at the international level (CSCMP, ELA, and BVL) are presented in Table 1.

Table 1. Comparative analysis of definitions of logistics as a science and practice

Criteria	Author's definition	The most common and generally accepted definitions		
		CSCMP (Council of Supply Chain Management Professionals)	ELA (European Logistics Association)	BVL (Bundesvereinigung Logistik)
Type of definition	Interdisciplinary, scientific and practical	Applied, functional, focused on flow management	Applied, focused on movement and placement	Application-oriented, scientific, with an emphasis on network modeling and sustainable development
Objects of management / research	Flows of material resources, information, finance, people, and related services; the logistics systems or networks within which these flows arise, function, and interact	Flows of goods and materials, services, information from source to consumer	Moving and placing goods and/or people, related activities	Economic systems as networks and flows of objects in space and time: goods, information, money, people
Focus, goal setting	Efficiency, creation of consumer value, competitiveness, sustainable development, interaction of people and technology	Satisfying customer requirements through effective flow management	Achieving the goals of the economic system	Design, analysis of networks and flows for the balanced achievement of economic, environmental and social goals
Level of coverage	Intra-organizational, inter-organizational, national, global, network	From the source of raw materials to the end consumer	Within a certain economic system	Within and between economic systems; emphasis on networks
Presence of the human aspect	Yes, people are among the objects of flows and as a key participant in interaction with technologies	No, emphasis on goods, services, information	Yes, people among the objects of displacement	Yes, people among the objects of flows
Strategic component	Directly stated: competitiveness, value creation, sustainable development	Partly stated: efficiency and satisfaction of needs, but strategicity is not directly emphasized	Depends on the context of the economic system, the strategic level is not detailed	Clearly expressed: network design, balanced development

The conducted comparative analysis allows us to state that the modern author's definition of logistics comprehensively combines key theoretical and practical aspects inherent in both classical and contemporary approaches to understanding this discipline. Unlike the traditional CSCMP definition, which primarily focuses on the applied level of managing flows of material resources, services, and information, the new interpretation of logistics views it as an interdisciplinary scientific and practical activity with a clearly expressed strategic orientation. The definition by the European Logistics Association (ELA) partially accounts for the human aspect, but its concept is limited to the confines of a single economic system and does not sufficiently emphasize the scientific and social components of logistics. The BVL definition is closest in meaning, positioning logistics as an application-oriented scientific discipline that models and analyzes economic systems as networks and flows of objects through time and space (specifically goods, information, money, and people) which create value for people. However, the new interpretation additionally emphasizes the role of the human element, interaction with technologies, and ensuring competitiveness in the context of globalization and sustainable development. Thus, the proposed definition of logistics reflects the current stage of this field's evolution, integrates approaches from classical schools, and aligns with the Logistics 5.0 concept.

Let's examine in more detail the object of research in logistics – flows as key components of logistics systems and networks, reflecting the movement and transformation of resources in space and time. We support the view that it is expedient to use the concept of a logistics flow as a system of interconnected and coordinated sub-flows of material resources, information, finances, and people, where each sub-flow has its own specific characteristics, parameters, and management mechanisms. Depending on the context of activity, one of these sub-flows may act as dominant, determining priorities in the planning, control, and optimization of logistics processes. This approach ensures flexibility in choosing management methods and tools, while maintaining the integrity of the logistics system or network as a single organism.

A logistics flow, as an integrated set of interconnected flows of material resources, information, finances, and people, is a dynamic system that constantly changes, transforms, and adapts according to the needs of the economic environment. The development of a logistics flow is accompanied by changes in its form, structure, and state, which manifest in:

– a transition from individual flow elements to integrated systemic interaction;

– the transformation of the primary (basic) flow form into a secondary (derivative) form, which arises from the interaction of sub-flows of different natures;

– the complication of the flow structure in the process of its development and the integration of new elements;

– a change in the functional state of the flow – from an active movement phase to a placement or accumulation stage, creating prerequisites for further efficient movement and use of resources.

A logistics flow has the following properties:

– multi-flow nature, meaning the inclusion of diverse sub-flows in its structure by nature and content (material, informational, financial, human);

– heterogeneity of elements, reflecting the variety of resources and information involved in the logistics process;

– spatial-temporal localization, meaning the defined spatial and temporal boundaries of the flow's functioning;

– goal orientation, as all flows are aimed at achieving a specific economic, social, or strategic goal;

– process consistency, which ensures the sequence, logic, and effectiveness of logistics operations;

– systemic organization, which implies the interconnection and interdependence of all components of the logistics flow and its integration into broader economic systems.

Under a traditional (non-logistical) approach, each link in the logistics flow has its own management system, oriented towards its own goals and efficiency criteria. The output flow of each preceding link, formed under the influence of that link's management system with its goals and criteria, serves as the input for the subsequent link. The resulting flow is the output flow of the last link, whose parameters are formed sequentially as a result of independent management influences. Under a logistical approach, management influences are exercised by a unified management system regarding the end-to-end main flow from the perspective of common goals and efficiency criteria. In this flow process, the following parameters can be managed: nomenclature of flow substance units (what needs to be delivered), flow volume (how much to deliver), destination (to whom to deliver), specified flow speed (when to deliver), fixed waiting intervals, and the conduct of intermediate and final control and regulation of flow processes at nodal points of movement.

The modern understanding of a logistics flow as an integrated set of interconnected material, informational, financial, and human flows, functioning in space and time, forms the basis for the development of logistics as an independent interdisciplinary science. The dynamic nature of flows, their ability to change structure, form, and functional state in response to external and internal influences, necessitates the application of scientifically sound approaches to their research and management.

Defining logistics as a science is a fundamental step towards understanding its essence, scope, and research boundaries. However, considering the complexity and multi-level nature of logistics flows, systems, and networks, it is important to consider logistics not only as a single whole but also in the context of different levels of aggregation and scales of functioning. This allows for a more precise analysis of the peculiarities of flow management and the interaction of elements of logistics systems at micro, meso, and macro levels. Therefore, the next logical step is a detailed consideration of the levels of logistics that define the scope of its application and the specifics of management processes in different contexts.

Based on the proposed definition of logistics and the presented thesis about the networked structure of flows, several levels of aggregation of logistical systems and networks can be clearly identified, corresponding to different scales of economic activity and complexities of logistical processes:

1. Micro-level (local level), which covers the logistics systems of individual enterprises, organizations, or very small business entities. Here, the management of flows of material resources, information, finance, and people occurs within a single organization or in a local market. Logistics networks at this level are characterized by a relatively simple structure, where the focus is on optimizing internal processes – procurement, production, warehousing, transportation, and delivery to the end consumer. The micro-level provides the basic functionality of logistics and serves as the foundation for more complex networks.

2. Meso-level (supply chains and constellations of interacting subjects) – this is the level where logistics networks are formed by integrating several enterprises, partners, or business units that interact within supply chains and value creation. At the meso-level, coordination of flows between subjects, relationship management, process synchronization, and optimization of the overall efficiency of the chain occur. It is at this level that the concepts of integrated logistics, supply chain management, and cooperation among market participants are implemented. The meso-level encompasses regional, inter-firm, or industry-specific logistics systems.

3. Macro-level – these are logistics networks that cover large-scale economic systems – entire economic sectors, regions, national economies, and global supply chains. Logistics at the macro-level is associated with the coordination and regulation of flows between different countries, continents, industries, ensuring infrastructural support, transport corridors, policies, and standards. Here, strategic planning, sustainable development, international cooperation, and global supply security are important issues.

Each of these levels is part of a higher-order network – local networks (micro-level) integrate into larger supply chains (meso-level), which, in turn, are elements of global economic systems (macro-level). Effective logistics management requires considering the specifics of each level and coordinating their interaction, which is critically important for achieving strategic, economic, and sustainable goals.

Logistics as a scientific approach finds wide application in various fields of activity, including military affairs, business, and emergency management. The generalized areas of use are presented in Fig. 2. Each of these areas has its specific requirements and features that determine the specifics of logistical support.

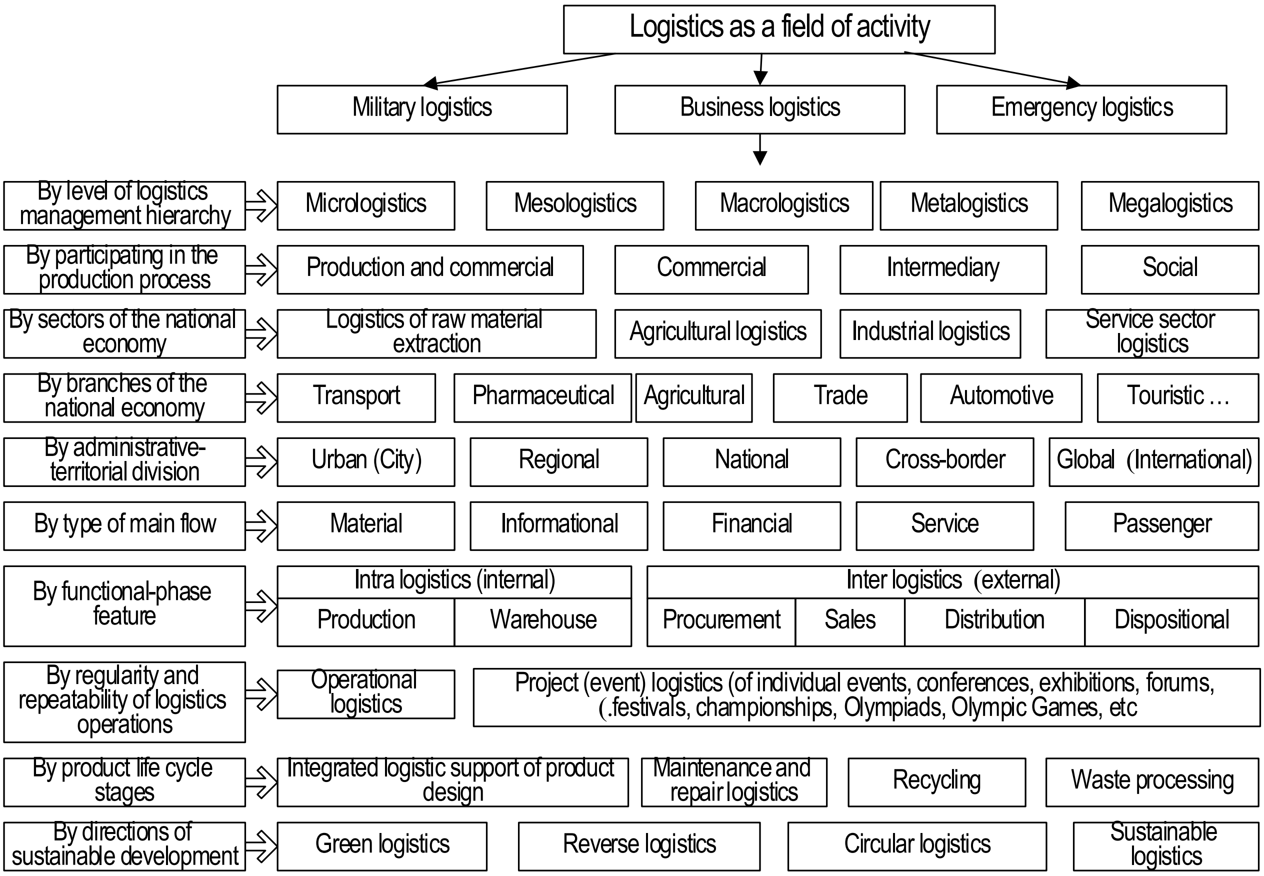

Figure 1 – Areas of application of logistics as a science and practice (designed by the author)

In the military field, logistics is a critically important component of ensuring combat readiness and successful execution of operations. It covers the planning, organization, and management of supplies of materials, armaments, fuel, medicines, and provisions, as well as the evacuation of the wounded and personnel rotation. Military logistics is characterized by high dynamism, the need for rapid adaptation to changes in the tactical situation, and strict requirements for reliability and security. It uses methods of comprehensive planning, coordination of transport and warehousing operations, and information systems for operational monitoring and resource management.

In business, logistics acts as a key element of supply chain management, ensuring the competitiveness of enterprises. It includes planning and controlling the movement of materials, goods, information, and financial flows from suppliers to end consumers. Business logistics aims to optimize costs, improve service levels, reduce inventory, and shorten order fulfillment times. It applies a wide range of methods and technologies, such as demand forecasting, automation of warehouse processes, transport optimization, and the use of ERP and SCM information systems.

In emergency management, logistics ensures rapid and effective response to crisis events, such as natural disasters, man-made accidents, epidemics, etc. Its main task is the quick mobilization, transportation, and distribution of humanitarian aid, medical supplies, equipment, and personnel to affected regions. The peculiarity of this area is the high unpredictability of situations, limited resources, and the need to coordinate numerous participants – government services, international organizations, and volunteer movements. Logistics in emergency situations applies adaptive planning, mobile warehouses, crisis information systems, and modern communication technologies to ensure timely and effective support.

Thus, logistics as a science provides a systemic, comprehensive, and adaptive approach to managing resource flows in various areas, considering their specific conditions and goals, which is a key factor in increasing the efficiency of activities in military affairs, business and crisis management.

Scientific research in logistics begins with the formulation of hypotheses – assumptions about the nature of interconnections and regularities in the functioning of logistics systems that are subject to empirical verification. Hypotheses act as working models that allow for directing research, structuring the problem, and defining the scope of analysis. In the context of the modern interpretation of logistics, a set of hypotheses, laws, and principles of logistics is proposed, which is presented in Fig. 2.

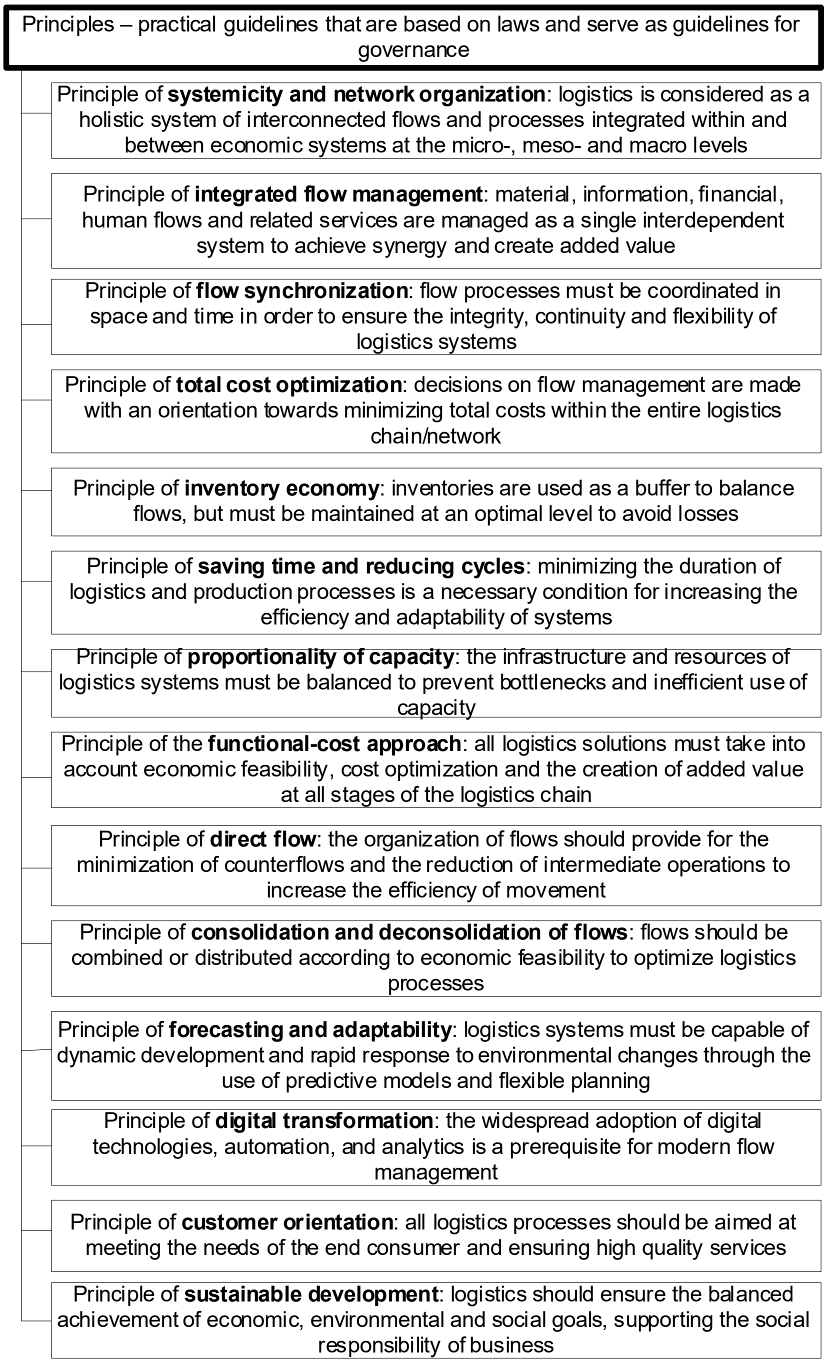

Figure 2 – Hierarchy of scientific concepts in logistics: from hypotheses to laws and principles of managing flows, systems, and networks (author's development)

The verification of identified hypotheses in logistics research allows for revealing objective regularities that determine the nature and limits of the functioning of logistics systems and networks. The laws of logistics as a science are based on a system of objective regularities that reflect essential and recurring connections between elements and processes of logistics systems and networks. These laws have a socio-economic character, so their operation depends on the specific context, technological level, scale, and structure of the system. However, it is precisely these laws that form the theoretical basis for the development of logistics concepts, the definition of key principles, and the selection of adequate management methods.

Within the scientific approach to logistics, it is advisable to distinguish groups of laws by their subject focus and functions. In particular, this work considers:

– laws of economy, which set fundamental rules for the rational use of resources and time within logistics systems or networks. They determine the need for comprehensive optimization of supply chains, minimization of inventory, reduction of logistics cycles, and selection of economically feasible flow routes;

– laws of organization, which define the structural and functional features of building and managing logistics networks and flows. They highlight the importance of flow consolidation, adequate infrastructure throughput, direct flow movement, and customer orientation as the basis for effective logistics activities;

– laws of digital transformation and sustainable development, which reflect modern trends and requirements for logistics systems, focusing on technological modernization, automation, environmental, and social responsibility.

The laws of logistics are interdisciplinary and apply to material, information, financial, and human flows, reflecting the complexity and strategic nature of the modern vision of logistics. It is on their basis that the principles of logistics process management are formed, detailing the ways of practical implementation of theoretical knowledge in the activities of enterprises, regions, and global economic systems.

Modern logistics is based on a system of principles that reflect the complex and multi-level nature of flow management in economic systems. System-integrative principles emphasize the integrity and interdependence of different types of flows, as well as the need for their synchronization to ensure the continuity and flexibility of logistics processes. Economic and optimization principles are aimed at minimizing total costs, effective inventory management, and reducing cycle times, which increases the adaptability and competitiveness of systems. Organizational and technological principles define the rules for building effective flows, considering direct flow, consolidation, and adaptability, as well as the implementation of digital technologies to increase transparency and operational efficiency. Socio-marketing principles emphasize the customer orientation of logistics services and the need to consider sustainable development, which ensures a balanced combination of economic, environmental, and social goals. Collectively, these principles create a reliable basis for the theoretical substantiation and practical implementation of modern logistics as a science and management function.

Based on laws and principles, a set of methods, tools, and technologies is formed that allows for effectively solving specific logistics tasks at various management levels – from operational to strategic. The sequence "laws → principles → methods" reflects the logical chain of transition from scientific knowledge to the practical implementation of management in logistics, ensuring the systematic nature, efficiency, and adaptability of logistics systems in modern conditions.

The complexity of logistics systems, manifested in multi-level organization, multi-flow nature, spatial-temporal localization, and systemic interdependence, requires the application of a comprehensive methodology. The methodology of logistics is not limited to the framework of a single discipline but integrates knowledge from various scientific fields for a comprehensive solution of logistics tasks. It combines knowledge from economics, management, informatics, mathematics, cybernetics, and social sciences. Specifically, from economics, it borrows principles of efficient resource utilization and cost analysis; from management – approaches to organizing, planning, and controlling processes; from informatics – methods of data processing, transfer, and protection; from mathematics – tools for modeling, optimization, and statistical analysis; from cybernetics – theories of managing complex systems and feedback; from social sciences – understanding of human behavior, organizational cultures, and social interactions. Such a multidisciplinary approach allows for comprehensively considering all aspects of logistics processes and increasing the efficiency of flow management in complex and dynamic conditions.

Thus, the methodology of logistics is considered as a set of conceptual approaches, principles, methods, and models applied to the analysis, design, organization, and optimization of logistics systems, networks, processes, and flows with the aim of increasing their efficiency, flexibility, and sustainable development of economic systems.

The methodology of logistics is based on three fundamental approaches – systemic, process, and flow – which form the basis for the analysis, design, and management of logistics flows, systems, and networks. The systemic approach in logistics is based on understanding logistics systems as complex, holistic entities consisting of interconnected elements, processes, resources, and participants. This approach allows for not considering individual logistics functions – transportation, warehousing, order management, cargo handling, last-mile delivery, returns management, information support – in isolation, but rather viewing them as parts of a single system, where changes or disruptions in one element inevitably affect the functioning of the entire system. The systemic approach involves a hierarchical structure of logistics systems (micro-, meso-, macro-levels), consideration of the external environment, goals, constraints, and interrelationships. This allows for a comprehensive analysis of logistics problems, building effective flow management models, and considering economic, technical, social, and environmental factors. The process approach focuses on logistics as a set of interconnected processes that have a clear sequence of execution, inputs, outputs, resources, and performance criteria. It ensures transparency, predictability, and manageability of logistics operations, allows for avoiding duplication of functions, loss of time and resources. The process approach is the basis for describing, optimizing, and standardizing logistics processes, implementing quality management systems, building process maps, and performance indicator (KPI) control systems. It orientates logistics towards achieving the final result – satisfying consumer needs and creating added customer value. The flow approach is a fundamental component of logistical thinking, as it allows for viewing economic systems and enterprises as networks through which various types of flows – material, informational, financial, and human – continuously move. This approach allows for modeling the structure, parameters, interaction, and dynamics of flows, as well as identifying "bottlenecks," imbalances, and potential for optimization. The flow approach ensures consistency and synchronization of different types of flows, allows for reducing inventory, cycle times, costs, and increasing service levels. It is precisely due to the flow approach that logistics acts as an integrating function of the economy, combining production, distribution, service, and consumption into a single managed system.

Thus, the combination of systemic, process, and flow approaches forms the conceptual basis of modern logistics as a science and practice, ensuring effective management of complex flow-network structures in conditions of increasing globalization, digitalization, and sustainable development. The defined methodological approaches – systemic, process, and flow – create the foundation for forming various concepts of logistics, which concretize and adapt general management principles to the specifics of different levels, industries, and operating conditions. The consideration of logistics concepts allows for a better understanding of how the science and practice of logistics have evolved under the influence of technological, economic, and social changes, and how they respond to modern challenges of globalization, digitalization, and sustainable development.

In modern academic and scientific literature, the definition of "logistics concept" is interpreted at two interrelated but distinct levels – theoretical and applied. At the theoretical level, a logistics concept is understood as a systemic model (paradigm) that reflects a fundamental vision of the role, structure, and tasks of logistics as a sphere of management within a specific historical, socio-economic, and technological context. Such concepts define logistics activities as a component of integrated enterprise management, supply chains, or economic systems of various levels. They lay the theoretical foundation for forming principles, methods, and approaches to organizing flows of material resources, information, finances, and people. Table 2 presents the author's vision of the evolution of the systemic model of logistics as a science, that is, as a sequential change in the scientific vision of the role, tasks, and boundaries of logistics in accordance with the development of economics, technologies, and societal needs.

Table 2. Stages of evolution of logistics as a science and applied discipline (author's development)

Stage	Characteristics of the system model	Object of management	Level of coverage	Key emphases of science and practice	Dominant laws and principles of logistics	Human role	Technological background
1. Stage of logistics conceptualization (1950–1970)	The emergence of theoretical ideas about logistics as an activity of moving and placing resources	Material flows	Enterprise, local level	Rationalization of transport, warehouse, costs, and organization of flows	Law of economic efficiency of flow movement (embryonic level), Principle of process organization	Human - physical performer, operator	Basic mechanization, initial information systems
2. Stage of logistics development and integration (1970–mid-1990s)	The formation of integrated logistics as a set of interconnected flows and processes	Material and information flows	Intra-firm and cross-functional	Integration of warehouse, transport and production processes; optimization of stocks; JIT, DRP concepts	Law of inventory saving, Law of time saving, Principle of systematicity, integration, process approach	Human - coordinator, manager, analyst	MRP, MRP II, first ERP systems
3. Stage of logistics separation and supply chain management (mid-1990s–2010)	Logistics as a component of SCM, focused on managing flows within interorganizational networks	Material, information and financial flows	Inter-organizational, inter-regional	Strategic integration, globalization, supply chain management, partnership and flexibility	Law of time saving, flow efficiency, consolidation, capacity proportionality; Principle of variability, integration, customer orientation	Human - key competence of the system, coordinator, strategic partner	ERP, EDI, SCM systems, analytics
4. Stage of logistics digital transformation (2010–2020)	Intellectualization of logistics systems, active digitalization of processes and management	Material, information, financial and human flows	From local to global	Digital platforms, transparency, analytics, automation and data integration	Strengthening the effect of the laws of flow efficiency, time saving, capacity proportionality; Principle of sustainable development, functional-value, digital approach	Human - analyst, user of digital technologies, operator of complex systems	Big Data, IoT, AI, blockchain, robotics
5. Stage of logistics intellectualization (from 2020)	Logistics as an interdisciplinary, global science and practice, focused on the	Material, information, financial and	Global, inter-industry, inter-regional	Human-centricity, sustainability, adaptability, ethics, social responsibility, integration of human	Synergistic effect of all laws of economy and organization; Principles of sustainable	Human - co-creator of the system, key beneficiary, bearer of	Industry 5.0, intelligent networks, Green

	balance of technology, sustainable development and people	human flows		and technological potential	development, systematicity, integration, customer orientation, human-centricity	knowledge and creativity	Logistics, ethical and social standards

The presented evolution of logistics as a science and practice reflects the gradual increase in the complexity of management objects and methods, as well as the rising level of integration and globalization of logistics systems. At the initial stage of conceptualization (1950–1970s), logistics was primarily viewed as a function of moving material resources within individual enterprises. During this period, basic laws of efficient flow movement dominated, and management mostly focused on rationalizing transport and warehousing. Humans performed physical executive functions, and technologies were limited to mechanization and rudimentary information systems.

During the period of logistics development and integration (1970s – mid-1990s), there was a significant expansion of the management object by including information flows and integrating inter-functional processes. Here, the laws of inventory and time economy gained strength, and systemic and integrated management principles were reinforced. Humans transformed into coordinators and analysts, and with the advent of technologies like MRP and ERP, optimization capabilities significantly increased.

From the mid-1990s to 2010, logistics formally separated from supply chain management, with the latter becoming key in globalization and inter-organizational coordination. Management encompassed material, information, and financial flows, emphasizing partnership, flexibility, and strategy. Laws of consolidation, proportionality of capacities, and customer orientation became critically important, and the human role transformed into a strategic partner capable of effectively managing complex networks with the help of SCM systems.

The stage of digital transformation (2010–2020) is characterized by the intensive use of innovative IT solutions – Big Data, artificial intelligence, Internet of Things, and robotization. This period deepens the application of sustainable development principles and the functional-value approach, ensuring flexibility, transparency, and accuracy in flow management. Humans remain key analysts and operators of complex automated systems.

Finally, the stage of intellectual logistics begins from 2020 and opens a new era, where technological progress combines with human-centricity, ethical standards, and social responsibility. Intellectual logistics means not only automation and digitalization of processes but also adaptability, self-learning, forecasting, and strategic decision-making, considering complex interrelationships between flows of materials, information, finance, and people. It harmoniously combines technological potential with a human-centric approach, sustainable development, and ethics, which is the essence of Logistics 5.0. This stage embodies systemic, integrated, and sustainable approaches, balancing economic efficiency with environmental and social aspects. Humans become not only users but also active creators of new-generation logistics systems, ensuring a balance between technologies and societal needs.

Thus, the presented model (paradigm) of logistics demonstrates not only technical-technological and organizational development, but also the gradual formation of a multi-dimensional scientific discipline, at the heart of which is effective, adaptive, and responsible management of resources, information, financial, and human flows in complex economic systems at various levels.

It should be noted that the evolution of logistics as a science and applied field is accompanied by the continuous development of concepts, strategies, management models, and practices that reflect changes in the technological environment, market conditions, and societal needs. From the perspective of a modern scientific vision, it is appropriate to distinguish three main groups of logistics concepts that characterize different stages and approaches to organizing logistics activities:

1. Traditional logistics concepts.

This group formed in the second half of the 20th century during the establishment of logistics as a separate management function and science. The main focus of traditional concepts is on managing material flows, optimizing costs, and ensuring the efficiency of resource provision. Among the key concepts of this period, the following should be highlighted:

– "Just-in-Time" (JIT) concept, which is focused on minimizing inventories and ensuring the supply of resources at a precisely defined time, which allows reducing storage costs and increasing turnover;

– "Just-in-Case" concept, which involves the formation of strategic reserves to reduce the risks of supply disruptions;

– Lean logistics, aimed at eliminating all types of losses in logistics processes and ensuring maximum value for the consumer at minimum costs;

– Outsourcing of logistics functions, i.e., transferring part of logistics processes to specialized companies to increase efficiency and flexibility. These concepts allowed for significant optimization of material flows, cost reduction, and increased productivity, but mostly did not take into account complex inter-system interconnections, social, and environmental aspects.

2. Integrated logistics concepts or SCM-oriented concepts:

– Quick Response (QR) and Continuous Replenishment (CR), which aim to shorten delivery times and ensure continuous replenishment of inventory based on up-to-date information on product sales levels;

– Efficient Consumer Response (ECR) – a concept aimed at increasing the efficiency of the entire supply chain through cooperation between manufacturers, wholesalers, and retailers for rapid response to consumer demand;

– Vendor-Managed Inventory (VMI) – an inventory management model where the supplier takes responsibility for planning and replenishing the consumer's inventory based on up-to-date inventory levels;

– Collaborative Planning, Forecasting, and Replenishment (CPFR) – a concept of joint demand planning, forecasting, and inventory replenishment, which involves deep cooperation between supply chain participants, information exchange, and coordination of actions to ensure the stability and efficiency of flows;

– Agile Logistics – a concept that focuses on the ability of the supply chain to quickly, efficiently, and with minimal cost adapt to changing market conditions, unpredictable demand changes, supply disruptions, and external crises.

Thus, SCM-oriented concepts demonstrate a transition from isolated management of individual flows to comprehensive (integrated) management of value chains.

3. Modern logistics concepts.

Starting from the 2010s, under the influence of digital transformations, globalization, and growing societal demands for sustainable development, there has been a qualitative change in approaches to logistics. Modern concepts integrate digital technologies, sustainability, social responsibility, and human-centricity. The main concepts of this stage include:

– Reverse Logistics – the concept emerged earlier but fully integrated into logistics only during the transition to sustainable development and responsible consumption;

– Circular Logistics – formed as a tool for implementing the circular economy and corresponds to the values of Logistics 5.0;

– Sustainable Logistics – oriented towards minimizing the negative impact of logistics processes on the environment, optimizing resource consumption, and developing a circular economy;

– Green Logistics – involves reducing greenhouse gas emissions, using environmentally friendly modes of transport, and ensuring energy efficiency of warehouses and logistics infrastructure;

– Digital Logistics – implemented through the introduction of information systems and digital technologies, including artificial intelligence, Internet of Things (IoT), blockchain, and big data to increase the transparency, flexibility, and accuracy of logistics operations;

– Smart Logistics – involves the integration of intelligent digital technologies (IoT, artificial intelligence, big data, automation, blockchain, etc.) into all elements of logistics systems to achieve maximum transparency of logistics processes in real-time;

– E-commerce Logistics – stimulates the development of quick, personalized, and convenient logistics services for online retail.

Thus, modern concepts go beyond exclusively economic efficiency, take into account environmental, social, and ethical aspects, and also focused on the integrated management of various types of flows (material, informational, financial, and human) in global logistics networks.

4. Logistics of the future: combining innovative technologies and a humanitarian approach.

Current trends in the development of science and practice allow us to predict the further transformation of logistics towards intellectual and human-centric logistics (Logistics 5.0). This approach combines the potential of technological innovations with the priority of humanitarian values. Key characteristics of future logistics:

– use of artificial intelligence, autonomous transport, robotic warehouses, digital twins for automation and optimization of processes;

– development of adaptive and self-learning logistics systems capable of responding to environmental changes in real-time;

– orientation towards human needs and safety, manifested in personalized logistics services, socially responsible management, and consideration of employee well-being;

– active integration of logistics into achieving Sustainable Development Goals (SDGs), particularly through supporting regional economies, circularity, and social inclusivity.

Thus, the described evolution of logistics concepts demonstrates a transition from narrow functional optimization to systemic, comprehensive flow management in a complex world where efficiency, technological advancement, and social responsibility act as a single integrated foundation. It clearly reflects the growing importance of the human factor, which makes the inclusion of human flows in the object of logistical analysis not only justified but also conceptually necessary. In the early stages of logistics development, particularly during the 1950s–1970s, the main focus was on managing material flows – goods, cargo, and inventory. Subsequently, during the period of integration of logistics functions (1970s–1990s), the idea of logistics as a system emerged, including not only material but also informational flows. Starting from the mid-1990s, with the spread of the supply chain management concept, logistics began to focus on inter-functional interaction, which is impossible without considering the movement, involvement, and interaction of people. In the era of digital transformation and the transition to Logistics 5.0, the importance of the human factor has grown even more: the object of logistical management now includes personnel, consumers, and users of logistics services, refugees, patients, and city residents – that is, all subjects whose movement in space and time requires logistical support. Applied fields confirm this expansion: military logistics has always considered personnel movement; in business logistics, the role of human resources logistics is growing; in humanitarian logistics – evacuation, resettlement, and support of people in emergency situations; in urban logistics – the organization of population mobility. Even leading logistics organizations, particularly BVL, explicitly include people in the list of objects of logistical modeling alongside goods, information, and finance. Thus, the inclusion of human flows in the modern definition of logistics corresponds to both applied practice and the scientific logic of logistics development as an interdisciplinary, human-oriented field of knowledge within the framework of Logistics 5.0.

The future development of logistics methodology as a science demonstrates its gradual transformation into an integrated, flexible, and predictive knowledge system that can not only accumulate approaches from other sciences but also influence their further development. As an interdisciplinary scientific field, logistics has from its very beginning relied on research results in the fields of economics, management, informatics, mathematics, cybernetics, engineering, sociology, and psychology. At the same time, the specificity of logistical thinking, namely the focus on flows, networks, interconnections, and goal orientation, allows for creating unique models capable of adequately reflecting the complex reality of modern dynamic systems.

In the near future, a key direction for the evolution of logistics methodology will be the development of virtual systems logistics. Modern logistics models are traditionally built on assumptions about the structuredness of economic systems, where roles, interconnections, and configurations are relatively stable. However, with the spread of digitalization, automation, and intellectualization of logistical activities in conditions of rapid change, these assumptions lose relevance. A new reality is forming – virtual logistics systems – in which elements and connections constantly change, boundaries between physical and digital space blur, and temporary, situational interaction networks emerge. For effective management of such systems, logistics must develop new methods for modeling, forecasting, and synchronizing flows, adapted to dynamic, non-linear, weakly structured environments.

Furthermore, logistics as a science is entering a phase of reverse influence on those scientific fields from which it drew knowledge. The specific paradigm formed in logistics, oriented towards managing flows in networks with consideration of multiple criteria, spatial-temporal coordination, and emergence, can be applied to the further development of business management, strategic planning, macroeconomic analysis, and also to fundamental disciplines. For example, in operations research, systems theory, and engineering sciences, logistical optimization and synchronization models already play a significant role. In the field of behavioral sciences, particularly psychology and sociology, logistics can offer approaches to modeling collective behavior in crisis conditions or in mass mobility systems. Thus, the logistics of the future is not just a science of flow management but also an integrative platform for mutual enrichment of various fields of knowledge, combining computational rigor, engineering precision, and socio-humanitarian sensitivity in the context of the complex challenges of the global world.

Conclusions. As a result of the conducted research, it is substantiated that logistics has transformed from an applied function related to the movement of material resources into a fully-fledged interdisciplinary scientific field. The modern interpretation of logistics goes beyond just operational management, encompassing strategic, social, and humanitarian dimensions. The refined definition of logistics within the article as the science of managing material, information, financial, and human flows within and between economic systems allows for uniting various approaches – from classical to digital and sustainable – into a single logical system.

In summary, it can be argued that the uniqueness of logistics as a science lies in its focus on the comprehensive study and management of integrated flows of material resources, information, finances, and human resources in space and time. Unlike other scientific disciplines that study individual types of flows in isolation (for instance, physics examines fluid and gas flows, economics analyzes financial flows, and information technologies investigate data flows), logistics views them as interconnected and dynamic systems that require specialized methods of analysis, planning, and management. This interdisciplinary and systemic approach defines logistics as an independent scientific discipline with a unique object and subject of research, which has significant practical importance for the effective functioning of complex economic systems.

The article proposes an original structure for the scientific foundation of logistics, encompassing the object of research, hypotheses, laws, principles, and methodological approaches. A system of logistics hypotheses has been formulated, consistent with the identified laws of economy and flow organization, as well as the principles of systematicity, process orientation, flow orientation, and adaptability. The proposed methodological basis combines the tools of economics, management, informatics, cybernetics, mathematics, and social sciences, confirming the interdisciplinary nature of logistics as a scientific field.

Five key stages of logistics development have been identified: from conceptualization in the mid-20th century to the current stage of Logistics 5.0, which is based on digitalization, service orientation, sustainable development, and consideration of the human factor. The content of traditional, SCM-oriented, and modern logistics concepts has been revealed, reflecting the shift in focus from managing physical flows to integrated management of complex, multifaceted logistics systems.

It is shown that the evolution of logistics as a science is accompanied by an increasing significance of the human factor, the emergence of virtual logistics networks, and the development of logistics in the fields of business, defense, and emergency management. It is emphasized that logistics approaches and models are increasingly becoming the basis for research and solutions in other scientific disciplines, indicating the growing reverse influence of logistics as a science.

The scientific novelty of the study lies in generalizing and conceptualizing the modern definition of logistics as a science, forming a structural-logical model of logistics from a scientific approach perspective, and proposing logic for the evolution of logistics concepts in connection with digitalization, sustainable development, and the humanization of flow management.

The practical significance lies in the fact that the obtained results can be used for updating educational programs in logistics and SCM, developing strategic logistics solutions in companies, and forming a new paradigm of logistical thinking in the context of the digital transformation of the economy.

Prospects for further research in the field of logistics should be based on the empirical verification of the identified principles and laws, which will allow for confirming their practical applicability and effectiveness in various contexts of logistics process management. Special attention should be paid to studying the formation and functioning of virtual logistics systems, which are becoming increasingly relevant in the conditions of digital transformation and a rapidly changing global environment. This research will help to develop new methodological approaches and tools for optimizing complex multi-level logistics networks. Furthermore, an important direction is the analysis of the humanitarian potential of logistics, especially in the context of crisis situations and recovery processes, which will increase the effectiveness of emergency response and promote the sustainable development of affected regions. Thus, further scientific research will contribute not only to the theoretical deepening of the discipline, but also to the practical adaptation of logistics concepts to contemporary challenges.

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Lazebnyk V. V. PhD in Economics, Associate Professor, Associate Professor of the Department of Marketing and International Trade, National University of Life and Environmental Sciences of Ukraine (Ukraine)

ORCID – 0000-0003-1581-5088
Researcher ID –
Scopus author id: – 59651303500
E-Mail: Asvika28@yahoo.com

INFORMATION AND PROCEDURAL SUPPORT FOR SALES MANAGEMENT IN THE SEGMENT OF PROFITABLE ORGANIC PRODUCT BRANDS

Viktoriia Lazebnyk. "Information and Procedural Support for Sales Management in the Segment of Profitable Organic Product Brands". *In the modern competitive landscape of the agri-food sector, effective sales management has become a critical factor in ensuring the profitability and sustainability of enterprises, particularly those operating in the premium, organic, and functional food segments. With increasing consumer expectations, seasonal fluctuations in demand, rising resource costs, and rapid digitalization, businesses must rethink traditional sales models and adopt innovative tools to maintain market competitiveness. This paper explores the role of information and procedural support in enhancing the effectiveness of sales management for profitable food brands, with a special emphasis on the impact of digital technologies.*

Information support encompasses the collection, analysis, and use of customer, product, and market data to improve demand forecasting, customize offerings, and mitigate risks. Procedural support, in turn, includes standardized algorithms, workflows, and regulations that coordinate actions across departments and improve customer service quality. The study presents a comprehensive review of recent research by Ukrainian and international scholars, confirming that the integration of CRM, ERP, BI systems, and other digital platforms contributes to operational efficiency, increased customer loyalty, and higher sales performance.

Through the case study of "HealthyChoice Foods," a leading food brand, the article provides empirical evidence of the transformative impact of digitalization. After implementing CRM and ERP systems, the company achieved a 40% reduction in order processing time, a 25% increase in repeat purchases, and a growth in annual sales from $12 million to $58 million. Standardization of processes, automation of logistics, and real-time analytics helped improve the Net Promoter Score (NPS) from 52 to 78, reflecting greater customer satisfaction and loyalty.

The paper also presents a set of practical recommendations for enterprises in the food sector, aimed at optimizing sales management through digital integration. These include implementing scalable CRM and ERP solutions, applying AI for demand forecasting, automating warehouse operations, unifying business procedures, and improving staff digital literacy. Special attention is given to overcoming common challenges *such as high implementation costs, employee resistance, technical limitations, and cybersecurity threats. A dedicated framework is provided to address these issues and ensure successful digital transformation.*

The study concludes that information and procedural support systems are not only technical instruments but also strategic resources that drive growth, efficiency, and customer trust. In high-margin segments such as organic food, the ability to personalize communication, streamline distribution, and predict customer behavior becomes a key differentiator. Therefore, enterprises that adopt a systemic and adaptive approach to sales management will be better positioned to respond to market volatility, meet consumer needs, and achieve long-term profitability.

The results of this research offer valuable insights for food industry enterprises developing digital transformation strategies and serve as a foundation for future scientific exploration into the integration of intelligent systems in sales management processes.

Keywords: sales management, profitable brands, organic products, information support, procedural support, CRM systems, digital transformation, analytics, personalization, agribusiness

Вікторія Лазебник. «Інформаційне та процедурне забезпечення управління продажами у сегменті прибуткових брендів органічних продуктів». *У статті розглянуто актуальні аспекти інформаційного та процедурного забезпечення управління продажами як ключового чинника підвищення ефективності комерційної діяльності підприємств в умовах сучасного бізнес-середовища. Особливу увагу приділено аналізу ролі сучасних інформаційних технологій, таких як CRM-системи, ERP-рішення та цифрові платформи, які забезпечують інтеграцію та автоматизацію процесів управління продажами. Досліджено вплив стандартизації та автоматизації процедур на зниження операційних витрат і підвищення рівня задоволеності клієнтів.*

На основі досвіду провідних компаній, зокрема Amazon, визначено ключові переваги впровадження інформаційних систем та аналітичних інструментів. Розроблено практичні рекомендації для підприємств щодо інтеграції сучасних технологій у бізнес-процеси, а також запропоновано шляхи подолання основних проблем і викликів, пов'язаних із впровадженням цих рішень.

Результати дослідження підкреслюють важливість адаптації до цифрових трансформацій, що дозволяє підприємствам підвищувати продуктивність, скорочувати витрати та забезпечувати конкурентоспроможність у швидко змінюваних умовах ринку..

Ключові слова: управління продажами, прибуткові бренди, органічні продукти, інформаційне забезпечення, процедурне забезпечення, CRM-системи, цифрова трансформація, аналітика, персоналізація, аграрний бізнес.

Intraduction. In the modern competitive environment of the agri-food sector, effective sales management is a crucial factor for the stability and profitability of enterprises dealing with organic food products. This is especially true for brands targeting the premium, organic, or functional segments, where not only product quality but also service speed, personalization, and logistical flexibility play a key role. High consumer expectations, seasonal demand fluctuations, rising resource costs, and rapid technological advancements require a rethinking of traditional sales approaches and their adaptation to new conditions.

In this context, information and procedural support becomes particularly important as it forms the foundation for decision-making and the efficient functioning of the sales system. Information support includes the collection, processing, and analysis of data related to customers, product range, market trends, and sales dynamics. This enables improved forecasting accuracy, strategic adaptation, and risk reduction. At the same time, procedural support involves the development of clear algorithms, regulations, and standards that optimize processes from order to delivery, ensuring coordination between departments and high service quality for customers.

The issue of effective sales management is gaining particular relevance in the era of digital transformation. The implementation of CRM and ERP systems, the use of artificial intelligence and analytical platforms, and the automation of warehouses and logistics are no longer just tools, but strategic drivers of growth for profitable food brands. However, the adoption of such solutions is accompanied by a range of barriers: high technology costs, the need for changes in organizational culture, a lack of qualified personnel, and cybersecurity risks.

Therefore, there is a pressing need for scientific justification of the role of information and procedural support in the sales management system of profitable organic food brands. It is important not only to identify their impact on the efficiency of sales processes but also to develop practical recommendations for overcoming digitalization barriers. This will enable enterprises to adapt to dynamic market changes and strengthen their competitiveness.

Analysis of recent research and publications. The topic of information and procedural support for sales management is actively explored by both Ukrainian and international scholars, who make a significant contribution to the development of this field. In particular, among Ukrainian researchers, Kryzhko O. and Darchuk V. [1] have analyzed the impact of information systems on marketing activities, specifically on the effectiveness of sales management in the context of Ukrainian enterprises. Berestetska O. and Riznyk N. [2], in their research, demonstrated that the implementation of CRM systems improves the accuracy of sales forecasting and reduces customer service time, which positively affects the overall efficiency of commercial operations.

Volianyk H. and Marushko N. [3] focused on procedural support, emphasizing the importance of business process standardization. They argue that process optimization reduces the risk of errors in the sales process and ensures higher customer satisfaction. Moreover, they underline that organizing internal control in the information process of management is a key direction in achieving successful operations of modern trading enterprises. In turn, the study by Pchelianska H. O. and Holovchuk Yu. O. [4] considers the specifics of building a brand of food products, taking into account market characteristics, consumer behavior, and the necessity of forming emotional attachment to the product. The authors emphasize that in a highly saturated market, the brand itself becomes a key differentiating factor capable of ensuring stable sales and customer loyalty.

Among international researchers, the theme of information support and sales management procedures is a vital component of marketing and business strategies. P. Kotler, in his works, highlights the integration of information systems for analyzing customer behavior, which allows for personalized brand offers tailored to specific consumer segments [5]. M. Porter [6] views the optimization of sales management procedures as an element of creating competitive advantages for the enterprise, showing that investments in information support contribute to profitability and operational cost efficiency.

Special attention in the literature is paid to the influence of digital tools on sales management. For instance, D. Aaker [7] emphasizes the importance of digital platforms and analytics in enhancing the effectiveness of brand sales, enabling more timely and effective customer engagement. A. Ross and M. Tyler [8] present sales management models based on the standardization of procedures and the use of modern analytical tools to achieve consistent results.

Thus, academic studies confirm that information and procedural support in managing sales of profitable food brands are critical factors for improving the effectiveness of commercial activity. The use of modern digital solutions – such as CRM and ERP systems, automated logistics modules, business analytics, and personalized marketing platforms – enables enterprises to respond swiftly to changes in demand, forecast sales more accurately, reduce costs, and strengthen customer loyalty. This not only contributes to increased productivity but also ensures that the brand remains adaptable to dynamic market conditions, maintains profitability, and sustains competitive positioning amid high consumer sensitivity and digital transformation.

The aim of the study is to substantiate the role of information and procedural support in the sales management of profitable organic food brands, as well as to identify effective approaches for their implementation to increase productivity, market adaptability, supply chain optimization, and ensure the long-term competitiveness of enterprises in the food industry. Particular attention is paid to the impact of digital solutions on forecasting accuracy, logistical flexibility, personalized customer interaction, and the stability of supply in the perishable segment of organic products.

Presentation of the main results. Modern information technologies such as CRM systems, ERP solutions, and digital platforms are radically transforming the approach to sales management for profitable food brands. These tools provide effective planning, execution, and control over all stages of the sales process, which is critically important in the highly competitive and high-margin food product segment.

The role of CRM systems in building brand loyalty. CRM systems (Customer Relationship Management) play a key role in building long-term consumer loyalty to food brands. They allow for tracking purchase history, customer preferences, responses to promotions and seasonal offers – particularly valuable in the FMCG segment. Personalized communications and targeted promotions boost repeat purchases, which is a decisive factor in brand profitability. According to research, the use of CRM solutions in the food industry increases the efficiency of loyalty programs and boosts sales volume by 20 – 30% through individualized customer strategies [2; 9].

ERP systems for process integration and efficiency. ERP systems (Enterprise Resource Planning) ensure the integration of production, logistics, and sales processes, enabling food brands to respond quickly to demand changes and avoid shortages or overproduction – especially important for products with limited shelf life. These solutions help automate orders, control inventory, and optimize logistics, reducing storage and transportation costs. For instance, Coca-Cola implemented an ERP system that reduced costs by 18% and sped up order processing by 30% [11].

Digital platforms and analytical tools as growth drivers. Digital platforms (online stores, marketplaces, mobile apps) expand the distribution channels of profitable food brands. The use of analytics enables the identification of consumption trends (e.g., the rising interest in gluten-free or organic products), rapid assortment adaptation, determination of the most profitable SKUs, and effective campaign planning. For example, the use of interactive sales analytics dashboards allows companies to promptly respond to changing customer preferences and meet peak period demand.

A practical confirmation of effectiveness is demonstrated by a Ukrainian company producing organic snacks. After implementing a CRM system, it increased repeat purchases by 25% and reduced customer acquisition costs by 15% thanks to precise analysis of consumer behavior.

Best practices from global leaders. Meanwhile, global food industry leaders such as Amazon Fresh and HealthyChoice Foods use ERP and CRM solutions combined with automated logistics systems to manage large volumes of products. This ensures rapid response to demand changes and consistent customer service quality [12; 13].

Thus, in the sector of profitable organic food brands, information technologies serve not only as tools for automation but also as strategic resources that shape competitive advantages, ensure accurate forecasting, improve service quality, and drive profitability through advanced analytics, personalization, and adaptability.

Table 1 presents a comparative analysis of key performance indicators of the organic brand "HealthyChoice Foods" before and after the implementation of modern information technologies such as CRM systems, ERP solutions, and analytical platforms. Prior to 2015, the company relied on traditional retail sales and manual order processing, which resulted in low operational efficiency and limited scalability.

Table 1 – Performance Results of the Organic Brand "HealthyChoice Foods" Before and After the Implementation of Modern Information Technologies

Indicator	Before Implementation of Modern Technologies (before 2015)	After Implementation of Modern Technologies (2016 and beyond)
Core Activity	Production and sale of organic products through traditional retail	Multichannel strategy: retail + e-commerce + HoReCa
Order Management	Manual order processing, errors in picking, long processing time	ERP system enabled automation of logistics and inventory management, reducing order processing time by 40%
Customer Interaction	Standard mailing, lack of personalization	CRM system enabled personalized offers, increased repeat purchases by 25%, and boosted average check size by 18%
Demand Forecasting	Gut-feel forecasting, dependent on manager experience	Integration of BI analytics reduced excess inventory by 22% and minimized returns through accurate seasonal demand forecasting
Marketing Campaigns	Local promotions with no performance tracking	Analytical platform enabled audience segmentation and effective digital campaigns, doubling advertising ROI
Annual Sales Volume	$12 million	$58 million in 2022 (due to expanded distribution and growth of online sales share to 35%)
Operating Profitability	7%	15% (due to automation, logistics optimization, and better demand planning)
Customer Satisfaction (NPS)	52	78 (improved service quality and delivery speed, launch of order-tracking mobile app)

Source: compiled by the author based on data from [13] and typical effects of ERP/CRM/BI implementation in food industry companies.

After the digital transformation launched in 2016, the brand implemented an ERP system to automate logistics and warehouse operations, a CRM platform for managing customer relations, and BI tools for analytics. This significantly reduced order processing time, increased personalization, lowered unsold inventory, and improved overall profitability.

The results demonstrate a significant increase in annual sales volume (from $12 million to $58 million), operational profitability (from 7% to 15%), and the Net Promoter Score (NPS) from 52 to 78 points. This confirms that the implementation of modern information technologies not only optimizes business processes but also fosters long-term competitiveness of profitable brands in the food sector [13].

HealthyChoice Foods stands as a prominent example of effective use of standardization and automation in managing profitable organic food brands. Through unified procedures for order processing, inventory management, logistics, and customer service, the company achieved significant gains in operational efficiency and customer satisfaction.

Benefits of unified operations across channels. The unification of processes enabled a stable level of service across all customer segments, regardless of distribution channel. Clear procedural algorithms significantly reduced the number of errors in order execution, which is critical for brands dealing with perishable goods. Moreover, standardization accelerated logistics operations and shortened the time between order receipt and delivery to the end consumer.

Simultaneously, process automation became a key component of the company's strategy. ERP solutions enabled efficient stock control, avoided overstocking, and optimized logistics and storage costs. The integration of a CRM system allowed for deeper analysis of customer behavior, personalized marketing offers, and increased repeat purchases. The use of business analytics tools enabled accurate demand forecasting, assortment adaptation to consumer preferences, and improved marketing campaign performance.

The introduction of digital delivery services, including integration with logistics operators, allowed the company to provide same-day delivery, positively impacting customer experience and brand loyalty. According to company estimates, the implementation of modern IT solutions reduced logistics and order processing costs by an average of 18 – 20%, while NPS rose from 52 to 78 points [13].

Thus, the experience of HealthyChoice Foods confirms that process standardization and automation are strategically important tools in managing profitable food brands. These approaches help reduce costs, improve productivity, build consumer trust, and ensure sustainable business growth in a dynamic market environment.

Practical recommendations based on experience. Studying the experience of technology implementation in companies allows for the development of a set of effective recommendations for the information and procedural support of sales management in profitable food brands, presented in Table 2. These recommendations can be adapted by businesses of all sizes – from local producers to international retail networks operating in the high value-added food product segment.

Table 2 – Recommendations for Implementing Information and Procedural Support for Sales of Profitable Organic Brands

Directions	Actions	Description of Activities
Implementation of Modern Information Systems	Integration of CRM Systems	Implementing CRM systems enables effective customer base management, personalized offers, and encourages repeat purchases through deeper segmentation.
	ERP Solutions for Process Integration	ERP systems optimize procurement, inventory, production, and logistics, which is especially important for perishable products.
	Analytical Platforms (BI Systems)	BI systems provide accurate demand forecasting, analysis of consumption trends, and profitability of each product line.
Business Process Automation	Warehouse Robotics	The use of automated storage and order picking systems reduces costs and increases service speed.
	Automated Sorting	Implementing sorting centers with minimal human involvement reduces errors and speeds up delivery.
	AI for Demand Forecasting	Machine learning models help detect sales patterns and prevent seasonal supply disruptions.
Standardization of Procedures	Process Unification	Creating unified operating standards across the network ensures consistent service quality regardless of the sales channel.
	Staff Training	Enhancing employee skills in digital tools supports effective integration of changes into daily operations.

	Procedure Documentation	Standardizing procedures facilitates business model scaling in new regions and improves quality control.
Enhancing Customer Orientation	Real-Time Order Tracking	Provides customers with transparency and confidence in the service, which is crucial for online food purchases.
	Personalized Offers	Using purchase history enables tailored recommendations, promotions, and cross-selling.
	Feedback Systems	Automatic post-purchase customer surveys allow prompt response to feedback and increase brand trust.
Investments in Innovation	Pilot Projects	Enables testing of new tools (e.g., chatbots, e-commerce platforms) without risking core operations.
	Integration with Suppliers	Using cloud platforms for data exchange ensures accurate deliveries and reduces shortages or delays.

Source: adapted by the author based on [14; 15; 16], and the analysis of modern sales management practices in the food industry.

The integration of digital tools allows for significant cost reductions, improved forecasting accuracy, personalized customer communications, and more effective assortment management – all of which are critical for brands aiming to maintain profitability in a highly competitive environment. Through business process automation and standardization, companies can reduce operating costs by 15 – 20%, increase customer loyalty, shorten order processing time, and deepen analytics regarding consumer preferences.

The application of the proposed approaches will not only support effective sales management but also strengthen the market position of the brand, particularly in the organic, functional, or premium food niches.

Barriers to implementation of information and procedural systems. The analysis of the problems and challenges faced by enterprises during the implementation of information and procedural support, presented in Table 3, highlights their complexity and multifaceted nature. The main barriers include high costs, technical difficulties, staff resistance, lack of qualified personnel, low levels of digital culture, and cybersecurity risks.

Table 3 – Challenges and Barriers to the Implementation of Information and Procedural Support and Ways to Overcome Them

Challenges	Solutions
High implementation costs	Cost optimization
Information systems such as CRM or ERP require significant investments in acquisition, configuration, and integration with existing processes. Additional training costs for personnel are also required.	• Choosing scalable solutions with the possibility of gradual implementation. • Using cloud services with lower initial infrastructure costs. • Applying for grants or participating in government digitalization support programs.
Resistance to change by personnel	Overcoming resistance to change
Employees may resist adopting new systems due to a lack of technical knowledge or fear of job loss due to automation.	• Conducting employee training focused on demonstrating the benefits of new technologies. • Implementing changes gradually, allowing sufficient time for adaptation. • Incentivizing employees, for example, with bonuses for successfully mastering new systems.
Technical difficulties	Resolving technical issues

Integrating new technologies with existing infrastructure may be challenging, especially if the enterprise uses outdated systems.	• Conducting a preliminary technical audit to assess the enterprise's readiness for implementation. • Engaging external experts or companies experienced in systems integration.
Lack of qualified specialists	Attracting qualified personnel
Enterprises may face a shortage of experienced professionals for system implementation and support.	• Investing in the professional development of current staff through certification programs. • Collaborating with educational institutions to attract young specialists. • Outsourcing system setup and maintenance tasks.
Low level of digital culture	Fostering digital culture
A lack of understanding of digitalization benefits among management or the absence of a strategic vision may hinder progress.	• Developing a digitalization strategy with clear goals and implementation stages. • Conducting information sessions for management to explain the long-term benefits of automation. • Demonstrating successful implementation examples.
Cybersecurity risks	Ensuring cybersecurity
The increasing amount of data processed by systems creates risks of unauthorized access or data loss.	• Installing modern data protection systems, including antivirus software. • Regular staff training on information security practices. • Conducting regular security audits and data backups.

Source: compiled by the author

However, the proposed ways to overcome the challenges associated with the implementation of information and procedural support make it possible to effectively minimize risks and ensure a successful transformation of the sales management system for profitable food brands. Cost optimization, investment in personnel training, involvement of industry experts, fostering digital culture among employees, and the implementation of data protection systems are critically important components for the successful digitalization of enterprises engaged in the production and distribution of food products.

Strengthening competitive advantage through a systematic approach. Enterprises that adopt a systematic approach to solving these problems gain the ability not only to implement effective digital solutions but also to significantly strengthen their competitive advantages in the market – especially in the context of dynamically changing consumer preferences, strict industry regulations, and high sensitivity to reputational risks. The rational integration of information systems such as CRM, ERP, and BI platforms enables real-time logistics optimization, assortment management, rapid demand response, and enhanced customer loyalty.

Thus, the implementation of information and procedural support in managing sales of profitable food brands is a complex but strategically essential step. Following the proposed recommendations contributes to reducing operational costs, improving service quality, enhancing personalized customer interaction, and forming long-term competitive advantages. In the digital economy, these factors are crucial for the successful operation of food companies focused on high profitability, innovation, and consumer trust.

Conclusions. This study highlights the strategic importance of information and procedural support in improving sales management efficiency within the segment of profitable organic product brands. It has been demonstrated that the implementation of modern digital tools – such as CRM systems, ERP solutions, and analytical platforms – not only automates business processes but also enhances customer interaction by enabling a personalized approach, reducing the sales cycle, and increasing consumer loyalty.

Particular emphasis has been placed on the procedural dimension, including process standardization, the development of clear operational algorithms, and internal regulations. These measures reduce risks and improve interdepartmental communication. Case study examples confirm that integrating information systems significantly improves performance indicators, demand forecasting accuracy, customer retention, and overall business profitability.

The findings of this research underscore that for organic brands, which position themselves as environmentally responsible, high-quality information and procedural support serves not merely as a technical instrument but as a foundation for trust, transparency, and competitiveness. In the era of digitalization and growing consumer expectations, agri-food enterprises must adopt adaptive and intelligent sales management strategies to secure sustainable development in both domestic and international markets.

Thus, a comprehensive approach to information and procedural support is a key success factor in the dynamic organic product market. Future research should focus on developing flexible management models based on artificial intelligence, integrating digital systems with supply chains, and analyzing real-time consumer behavior to further enhance sales performance and business resilience.

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Gurina G. S. Doctor of economic sciences, professor, professor department of management of foreign economic activity of enterprises State University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0000-0002-1419-4956
Researcher ID –
Scopus author id: –
E-Mail: hanna.hurina@npp.kai.edu.ua

Podrieza S.M. Doctor of economic sciences, professor, professor department of management of foreign economic activity of enterprises State University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0000-0003-2396-9570
Researcher ID –
Scopus author id: –
E-Mail: serhii.podrieza@npp.kai.edu.ua

Novak V. O. PhD in Economics, Professor of Management of Foreign Economic Activity of Enterprises Department State University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0000-0001-6899-2016
Researcher ID –
Scopus author id: –
E-Mail: valentyna.novak@npp.kai.edu.ua

Tseluiko O. I. Candidate of Science in Public Administration, Associate Professor, Associate Professor of the Department of Public Administration and Land Management of the Classical Private University, Zaporizhzhia (Ukraine)

ORCID – 0000-0002-9782-5011
Researcher ID –
Scopus author id: –
E-Mail: katya_373@ukr.net

INSTITUTIONALIZATION OF CUSTOMS PROCEDURES AS A STRATEGIC TOOL FOR ECONOMIC SECURITY: A PROACTIVE APPROACH IN THE MANAGEMENT OF UKRAINE'S FOREIGN ECONOMIC ACTIVITY

Ganna Gurina, Serhii Podrieza, Valentyna Novak, Oleksii Tseluiko. "Institutionalization of customs procedures as a strategic tool for economic security: a proactive approach in the management of Ukraine's foreign economic activity". *This article explores the transformation of Ukraine's customs policy under martial law as a key instrument for ensuring the country's economic security. The authors emphasize the institutionalization of customs procedures-customs control, clearance, and the collection of taxes and duties - as a strategic mechanism for strengthening foreign economic activity. In wartime conditions, the customs system functions not only as a regulator but also as a proactive element of state governance, supporting domestic producers, the Armed Forces of Ukraine, and civil society. The methodological framework of the study includes comparative analysis, abstraction, structural modeling, and generalization. As a result, the essence and components of customs procedures were defined, and changes introduced into legislation and customs practice under unprecedented challenges were identified. The study also examines the interconnection between customs policy and the national strategy for economic security, particularly in supporting critical infrastructure and supply chains. The importance of digitalizing customs procedures is highlighted as a means of increasing transparency and responsiveness during crises. The authors stress the need for adaptive legislation capable of responding to evolving external threats. Prospects for integrating international experience in customs administration are outlined to strengthen Ukraine's institutional capacity. The article lays the foundation for further research in the field of security-oriented management of foreign economic activity. The proposed conclusions can serve as an analytical tool for developing policies in the field of economic security in conditions of instability.*

Keywords*:* customs policy, martial law, economic security, institutionalization, customs procedures, proactive governance, foreign economic activity, digitalization, legislative adaptation, humanitarian aid, supply chain resilience, national recovery, crisis management, governance instruments, strategic, administrative tools

Ганна Гуріна, Сергій Подрієза, Валентина Новак, Олексій Целуйко. «Інституціоналізація митних процедур як стратегічний інструмент економічної безпеки: проактивний підхід в управлінні зовнішньоекономічною діяльністю України». *У статті досліджується трансформація митної політики України в умовах воєнного стану як ключового інструмента забезпечення економічної безпеки держави. Автори акцентують увагу на інституціоналізації митних процедур - митного контролю, оформлення та стягнення податків і зборів - як стратегічного механізму посилення зовнішньоекономічної діяльності. В умовах війни митна система функціонує не лише як регулятор, а й як проактивний елемент державного управління, підтримуючи вітчизняних виробників, Збройні Сили України та громадянське суспільство. Методологічну основу дослідження становлять порівняльний аналіз, абстрагування, структурне моделювання та узагальнення. У результаті було визначено сутність і складові митних процедур, а також виявлено зміни, запроваджені в законодавстві та митній практиці в умовах безпрецедентних викликів. Досліджено взаємозв'язок між митною політикою та національною стратегією економічної безпеки, зокрема в аспекті підтримки критичної інфраструктури та логістичних ланцюгів. Підкреслено важливість цифровізації митних процедур як засобу підвищення прозорості та оперативності в умовах криз. Автори наголошують на потребі адаптивного законодавства, здатного реагувати на змінні зовнішні загрози. Окреслено перспективи інтеграції міжнародного досвіду в митному адмініструванні з метою посилення інституційної спроможності України. Стаття закладає основу для подальших досліджень у сфері безпеково-орієнтованого управління зовнішньоекономічною діяльністю. Запропоновані висновки можуть слугувати аналітичним інструментом для розробки політик у сфері економічної безпеки в умовах нестабільності.*

Ключові слова: митна політика, воєнний стан, економічна безпека, інституціоналізація, митні процедури, проактивне управління, зовнішньоекономічна діяльність, цифровізація, адаптація законодавства, гуманітарна допомога, стійкість ланцюгів постачання, національне відновлення, кризове управління, стратегія, інструменти управління.

Introduction. The full-scale war in Ukraine has triggered unprecedented shifts in the country's economic governance, placing customs policy at the forefront of national resilience and security. As a strategic interface between domestic production and international trade, the customs system has evolved from a regulatory mechanism into a proactive instrument of statecraft. In conditions of martial law, customs procedures—ranging from control and clearance to taxation—have been reconfigured to support the Armed Forces, safeguard critical infrastructure, and stimulate national industry. This transformation reflects not only a response to external threats but also a deliberate institutional adaptation aimed at reinforcing economic sovereignty. The urgency of these reforms has catalyzed legislative innovation, digital modernization, and the integration of security imperatives into economic policy. This study examines the structural and functional metamorphosis of Ukraine's customs administration, offering a conceptual model of proactive customs policy as a stabilizing force in times of crisis. This reconfiguration of customs governance reflects a broader paradigm shift in Ukraine's approach to economic resilience—one that prioritizes agility, institutional robustness, and strategic foresight. In this context, customs policy is no longer confined to transactional oversight but is embedded within a national security framework that demands anticipatory action and cross-sectoral coordination. The integration of customs functions with defense logistics, humanitarian aid flows, and industrial policy underscores their expanded role in sustaining wartime economic functionality. Moreover, the acceleration of digital tools and risk-based management systems has enabled more targeted interventions, minimizing disruptions while maximizing fiscal efficiency. These developments signal the emergence of a hybrid model of customs administration—simultaneously reactive to immediate threats and proactive in shaping long-term recovery and competitiveness.

Literature review. The evolution of customs policy in crisis contexts has been the subject of growing scholarly attention, particularly in relation to its role in economic stabilization and national security. Existing literature underscores the dual nature of customs administration—as both a fiscal instrument and a gatekeeper of strategic resources (Brunet & Cadot, 2020; Gasiorek et al., 2022). In the Ukrainian context, pre-war studies primarily focused on trade facilitation, anti-corruption measures, and harmonization with EU standards (Kravchuk, 2019; Melnyk & Horbenko, 2021). However, the onset of full-scale war has prompted a shift in academic discourse toward resilience, institutional adaptability, and the securitization of economic governance. Recent contributions highlight the necessity of integrating customs operations into broader defense and humanitarian frameworks (OECD, 2023; UNCTAD, 2022). Scholars have examined the role of expedited procedures, temporary exemptions, and digital platforms in maintaining supply chain continuity under duress (Ivanova & Shevchuk, 2023). Moreover, comparative analyses of post-conflict economies suggest that proactive customs policy can serve as a catalyst for reconstruction and industrial renewal (Baldwin & Evenett, 2021).

Despite these insights, there remains a gap in the literature regarding the operationalization of customs policy as a dynamic security tool in real-time conflict scenarios. This study addresses that gap by offering a conceptual model rooted in Ukraine's wartime experience, emphasizing the intersection of institutional reform, legislative agility, and strategic foresight.

Purpose and objectives. The purpose of this study is to examine the transformation of Ukraine's customs policy under martial law as a strategic mechanism for reinforcing economic security and institutional resilience. In light of the war's disruptive impact on trade, logistics, and fiscal stability, customs administration has acquired a new significance—not merely as a regulatory function, but as a dynamic tool of statecraft. This research seeks to explore how customs procedures have been restructured to support national production, defense operations, and humanitarian flows, while simultaneously adapting to legislative shifts and technological modernization. By analyzing these developments, the study aims to conceptualize a proactive model of customs governance that integrates security imperatives with economic recovery strategies. The inquiry is grounded in the belief that customs policy, when strategically aligned with broader national objectives, can serve as a stabilizing force in both crisis and post-crisis contexts.

Results, analysis, and discussion. The analysis reveals a marked shift in the operational logic of Ukraine's customs administration during martial law, characterized by accelerated procedural flexibility, targeted fiscal exemptions, and enhanced coordination with defense and humanitarian agencies. One of the most significant outcomes has been the institutionalization of expedited customs clearance for military and dual-use goods, which has reduced logistical bottlenecks and improved supply chain responsiveness. Simultaneously, the introduction of temporary tax relief measures for critical imports—such as medical supplies, fuel, and construction materials—has supported both civilian resilience and infrastructure recovery.

Digitalization has played a pivotal role in sustaining operational continuity. The deployment of automated risk management systems and remote declaration platforms has not only minimized physical contact during wartime but also improved transparency and reduced corruption risks. These innovations have enabled customs authorities to prioritize high-risk consignments while streamlining low-risk flows, thereby optimizing resource allocation under constrained conditions.

Legislative amendments enacted during the conflict reflect a shift toward adaptive governance. The simplification of customs codes, the temporary suspension of certain duties, and the alignment of customs procedures with emergency procurement frameworks demonstrate a strategic recalibration of regulatory priorities. Importantly, these changes have been accompanied by increased inter-agency collaboration, particularly between the State Customs Service, the Ministry of Defense, and civil society organizations.

From a broader perspective, the wartime transformation of customs policy illustrates the potential of institutional agility in safeguarding economic sovereignty. Rather than merely reacting to external shocks, Ukraine's customs system has begun to anticipate and shape the contours of post-war recovery. This proactive stance—anchored in legal innovation, digital modernization, and strategic alignment—offers a blueprint for other nations navigating complex security-economic intersections.

The full-scale invasion of Ukraine by russian aggressors has had a profound impact on various segments of the national economy. In light of external threats to the functioning of foreign economic activity and the financial system as a whole, there arises an urgent need to develop and implement new aspects of domestic customs policy that ensure its effective operation.

State customs policy is a vital component of national economic policy. Its essence lies in a system of principles and directions guiding the state's activities in the field of protecting customs interests and ensuring Ukraine's customs security, regulating foreign trade, safeguarding the domestic market, fostering economic development, and facilitating the country's integration into the global economy [1].

Customs policy during the full-scale war has a number of specific features that require careful attention and analysis. At first glance, it may appear that war affects the customs regime primarily through changes in trade flows and the value of goods. However, customs policy has deeper implications for the country's economy and security that warrant closer examination.

One of the most evident consequences of the full-scale war is the disruption and redirection of trade flows. As a country at war, Ukraine is compelled to adjust its customs policy in response to developments on the front lines and the state of foreign trade. For instance, in the event of enemy blockades of certain territories where export-oriented enterprises operate, the government may revise import tariffs on similar goods to reduce dependence on supplies from those regions.

Following the onset of the full-scale invasion of Ukraine, a significant number of regulatory acts were adopted to simplify the procedures for processing goods and vehicles. These measures aim to facilitate the swift, unobstructed, and comprehensive provision of essential supplies to the population and the Armed Forces of Ukraine during this critical period [5]. As a result of the blockade of seaports, the structure of supply chains has undergone substantial changes, with a shift toward rail and road transportation. To accelerate the movement of goods, control procedures have been streamlined, dedicated lanes for cargo transport have been established, personnel have been redistributed, and the number of customs officers at checkpoints has been increased. Effective communication has also been established between post supervisors and senior operational staff with representatives of volunteer organizations to ensure timely receipt of information regarding incoming humanitarian aid [6].

Additionally, Cabinet of Ministers Resolution No. 174 dated March 1, 2022, "Certain Issues Regarding the Passage of Humanitarian Aid Across the Customs Border of Ukraine Under Martial Law," stipulates that during martial law, humanitarian aid may be cleared at the point of crossing the customs border of Ukraine by submitting a declaration in paper or electronic form, completed by the person transporting the goods. This process is carried out without the application of non-tariff regulation measures for foreign economic activity and without the requirement to submit guarantee letters [7].

The full-scale war in Ukraine has profoundly reshaped the country's customs policy, turning it into a strategic instrument of national resilience rather than merely a regulator of foreign trade. One of the most significant shifts has been the disruption of trade flows, rated at an impact level of 8, due to widespread blockades and frontline instability that forced the rerouting of import and export logistics. The adjustment of import tariffs received a slightly lower score of 6, reflecting the selective nature of these changes, which were implemented to reduce dependence on goods from occupied regions but did not comprehensively cover all product categories. In contrast, the simplification of customs procedures was assigned a high impact level of 9, as it became essential for ensuring rapid clearance of goods - especially those destined for the Armed Forces and civilian populations.

Table 1 – Impact of Customs Policy Changes During Full-Scale War

Policy Area	Description of Changes	Impact Level
Disruption of Trade Flows	Rerouting due to blockades and frontline developments	8
Adjustment of Import Tariffs	Reducing dependence on goods from blocked regions	6
Simplification of Customs Procedures	Faster processing of goods and vehicles	9
Shift in Transportation Routes	Transition from seaports to rail and road transport	7
Reduction of Control Procedures	Dedicated lanes, increased staff, accelerated inspections	8
Humanitarian Aid	Simplified declaration without non-tariff regulation or guarantee letters	9

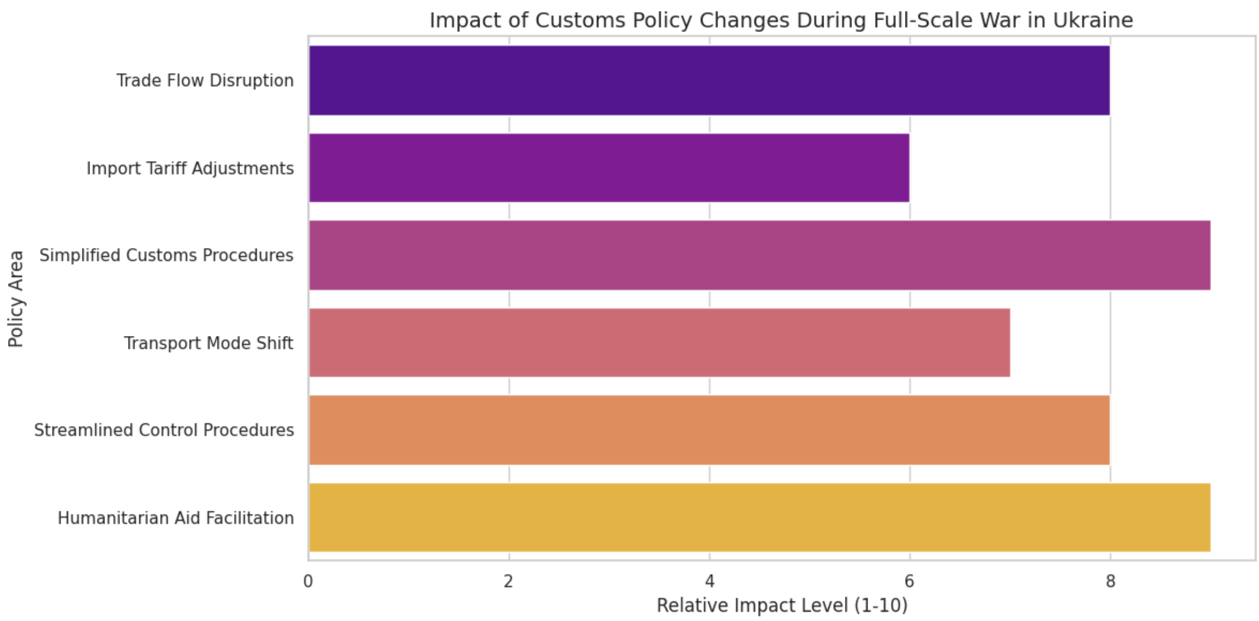

Figure 1 – Key changes in Ukraine's customs policy in the context of a full-scale war.
Source: compiled by the authors based on data from [2,4,5,8,12,13,14,15,16].

The shift in transportation routes, rated at 7, illustrates a substantial but not complete transition from seaports to rail and road networks, requiring significant infrastructural adaptation. The reduction of control procedures also scored 8, acknowledging the creation of dedicated lanes, increased staffing, and accelerated inspections that minimized delays at border crossings. Humanitarian aid procedures were rated at the highest level of 9, justified by the complete deregulation of its customs clearance - eliminating non-tariff barriers and guarantee requirements to ensure swift delivery (tabl.1, fig.1). These changes reflect not only economic necessity but also strategic urgency, as customs policy became a frontline tool in maintaining national functionality under martial law. The high scores across most categories demonstrate the adaptability of Ukraine's customs system in response to wartime challenges. Meanwhile, the relatively lower score for tariff adjustments highlights the complexity of legislative processes and the need to balance domestic production support with import accessibility. Overall, the chart and table illustrate how customs policy evolved into a mechanism of national security, with its impact extending far beyond traditional economic boundaries.

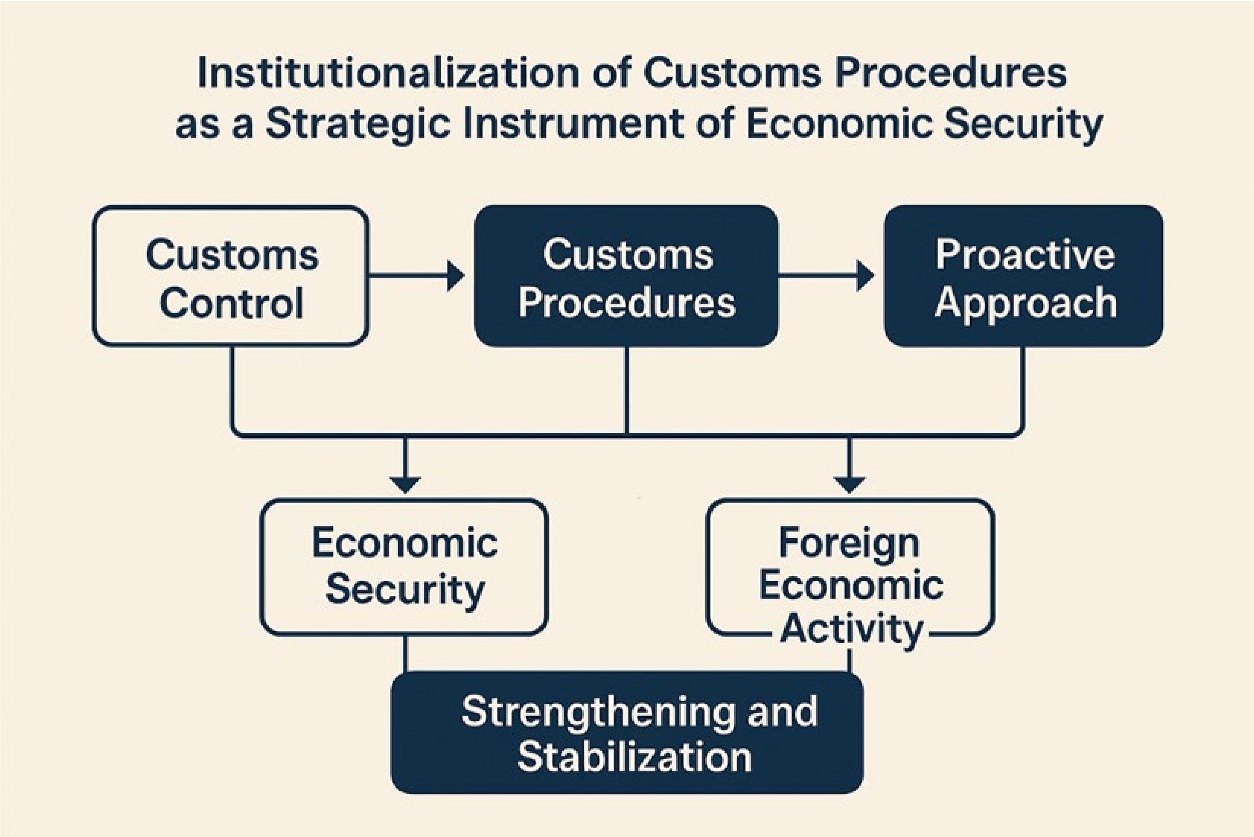

Figure 2 – Institutionalization of customs procedures as a strategic instrument of economic security [1,3,6]

A study of the specificities of the activities of customs authorities under martial law in Ukraine allowed us to conclude that they are highly effective in promptly taking measures to simplify the movement of goods of critical importance to the economy and the Defense Forces across the customs border of the state. However, a study of the work of customs authorities in ensuring transparency of the movement of goods across the customs border of Ukraine, completeness of accounting for the cost of exports and imports, and the quality of providing customs services to clients indicates an extremely low level of effectiveness of this work. Indeed, due to the persistence of a high level of corruption, imports in the amount of 4.2 billion dollars and exports in the amount of 2.4 billion dollars remained unaccounted for at the customs, which significantly affected the volumes of receipts of customs taxation payments and foreign economic activity. Participants in foreign economic activity (both individuals and business entities) have the opportunity to choose only one of the forms of organizing customs procedures proposed in the Resolution of the Cabinet of Ministers No. 330. At the same time, if a simplified method is chosen, the subject of legal relations submits a corresponding application in the form established by the State Customs Service of Ukraine, using its paper or electronic format. Certain restrictions are also provided for the application of the simplified method of organizing customs control and customs clearance, in particular, for business entities that import the following items into the customs territory of Ukraine: - ethyl alcohol and other alcoholic distillates; - alcoholic beverages and beer; - tobacco products, tobacco, industrial tobacco substitutes, cigarettes, cigarillos, cigarillos and liquids used in electronic cigarettes. Thus, the Resolution of the Cabinet of Ministers No. 330 is aimed at the maximum simplification of customs procedures, determining the possibilities of their organization by submitting a preliminary customs declaration in a simplified form by the declarant to the customs authority directly at checkpoints (control points) across the state and customs border of Ukraine and receiving the results of customs procedures within a period of no more than ten minutes [10]. This order of organization of customs procedures was proposed by the Government only for the period of martial law in the state, which is fully justified by the difficult conditions of war, when certain needs of military personnel and citizens who find themselves in difficult life circumstances are difficult to cover with the internal reserves of the state. This factor was also reflected in the Resolution of the Cabinet of Ministers No. 330, in particular regarding the organization of customs procedures when importing humanitarian aid into the customs territory of Ukraine. Thus, the document stipulates that the passage of humanitarian aid, military goods, medicines and medical products is carried out immediately through a special channel without customs inspection and without relevant decisions of the regional state administration/regional administration on the recognition of such goods as humanitarian aid [10]. MANAGEMENT Secondly, the Government proposed to postpone the payment of customs duties for some of the items subject to import into the customs territory of Ukraine, namely [11]: - medicines permitted for production and use in Ukraine and included in the State Register of Medicines; - medical products included in the State Register of Medical Equipment and Medical Products or meeting the requirements of the relevant technical regulations; – certain categories of food products; – goods specified in the list of military goods, which is regulated not only by the Resolution of the Cabinet of Ministers of Ukraine No. 236 [11], but also by the Appendix to the Procedure for State Control over International Transfers of Military Goods, approved by the Resolution of the Cabinet of Ministers of Ukraine No. 1807 [12]; – goods of critical import, the list of which is given in the Resolution of the Cabinet of Ministers of Ukraine No. 153 [13]. Thirdly, the Government has made significant changes to the customs clearance procedure for cars imported into the customs territory of Ukraine. In particular, "from April 1, 2022 (temporarily, for the period of martial law in the territory of Ukraine) transactions involving the import by individuals into the customs territory of Ukraine of passenger cars, their bodies, trailers and semi-trailers, motorcycles, vehicles intended for the transport of 10 or more people, vehicles for the transport of cargo under the customs import regime" [14], and also "from April 1, 2022 for the period of martial law in the territory of Ukraine, transactions involving the import of goods into the customs territory of Ukraine under the customs import regime by business entities registered as single tax payers of the first, second and third groups" [14], except for individuals and legal entities of certain categories defined by Law No. 2142-IX, which amends the PKU. In fact, such a step was proposed within the framework of expanding the base to meet the needs of the Armed

Forces of Ukraine (hereinafter referred to as the AFU) in vehicles, as well as supporting businesses engaged in foreign economic activity. If the abolition of customs payments for certain categories of business entities did indeed have the effect of supporting foreign economic activity, then, as the practice of implementing changes in the area of car customs clearance has shown, most civilians used this opportunity to purchase vehicles for personal needs, which ultimately had no advantages in the context of ensuring foreign economic activity. This aspect has two sides: on the one hand, the dynamic decline in the population's incomes, the decline in employment, the reduction of working cities and massive business losses from the occupation of a significant portion of Ukrainian territories (which is slightly more than 20.0% of the total area of Ukraine) lead to citizens' search for ways to minimize costs, in fact, induces them to use the opportunity to purchase cars with "zero customs clearance"; on the other hand, realizing the importance of providing the Armed Forces of Ukraine, as well as economic entities in war conditions, this document, in our opinion, requires revisions, in particular, it should define certain restrictions for civilians. Taking into account the primary needs of the military in vehicles, it is important to understand that this document was adopted to support the Armed Forces of Ukraine. Accordingly, the mass purchase of cars by civilians under simplified customs procedures and "zero customs clearance" leads to a slowdown in the work of customs offices and significant losses to the State Budget, further complicating the financial and economic situation of the state. The options for customs control and clearance of goods (including motor vehicles) imported into the customs territory of Ukraine, proposed by the Government in the above-mentioned documents, create unprecedented opportunities for Ukrainian companies to independently choose the most optimal way to declare customs operations during the period of martial law, without disrupting the functionality of customs, tax and banking institutions. The authorized authorities, customs authorities, the Government, and the Verkhovna Rada, even in the context of dynamic transformations of the foreign economic activity structure and customs policy, are trying to work in a coordinated manner and take balanced steps that will play an important role in the long term in the context of not only improving the organization of customs procedures, but also the sustainability of the development of the Ukrainian economy in general. Thus, consideration of the government bill on customs clearance of cars through the Ukrainian digital application "Diya" [16] will be of great importance. Such a service can be considered unprecedented, since it actually has no effective analogues in the world. The primary task of this stage is to work out issues related to customs clearance of electric cars. Successful practical organization and implementation of the Government's plan will have a positive effect both for business and the state within the framework of supporting foreign economic activity, and for citizens. The practice of organizing customs procedures for foreign economic activity in Ukraine provides for a set of measures to control and register goods, services or other objects crossing the customs border of Ukraine, as well as the procedure for paying the relevant fees and taxes to the budget. The war significantly influenced the change in the organization of the work of the State Customs Service, which required the introduction of appropriate changes in the regulatory and legal documents and the legislative framework of Ukraine. However, the issue of organizing customs procedures during the war, even in the context of the steps already taken, does not lose its relevance. Reforming the organization of the work of the customs service and streamlining the implementation of customs procedures are tasks that have long been a priority. It is in the circumstances of a critical situation that it is advisable to mobilize all available potential and use it not only to overcome current problems, but also as a basis for post-war reconstruction. Given the importance of foreign economic activity for Ukraine as a participant in the global market, as well as domestic business, which is able to offer the world high-quality goods with high added value, and not just raw materials, work on streamlining customs procedures should continue. Only protection and support for national producers will ensure their uninterrupted operation and maintenance of competitive positions on the world market even in wartime, and simplification of customs procedures in the import process will significantly optimize the provision of the needs of both Ukrainian citizens and the Armed Forces of Ukraine.

Conclusions. The transformation of Ukraine's customs policy under martial law has demonstrated the critical role of institutional agility in safeguarding economic security during times of crisis. Far beyond its traditional regulatory function, customs administration has emerged as a strategic instrument of state resilience, capable of adapting to rapidly shifting geopolitical and logistical realities. The disruption of trade flows, reconfiguration of transportation routes, and targeted tariff adjustments reflect a dynamic response to external threats and internal vulnerabilities. Simplified customs procedures and the deregulation of humanitarian aid clearance have proven essential in maintaining supply chain continuity and supporting both civilian and military needs. These measures underscore the importance of proactive governance, where regulatory frameworks are not static but evolve in alignment with national priorities. The high impact levels observed across most policy areas affirm the effectiveness of Ukraine's adaptive approach, particularly in accelerating clearance processes and minimizing bureaucratic friction. Digitalization and inter-agency coordination have further enhanced operational efficiency, transparency, and responsiveness. At the same time, the relatively lower impact of tariff adjustments highlights the constraints of legislative inertia and the complexity of balancing protectionism with market access. The integration of customs policy into broader security and recovery strategies marks a paradigm shift in economic governance. It illustrates how border management can serve not only fiscal and trade objectives but also humanitarian, defense, and strategic functions. The institutionalization of these wartime reforms offers a blueprint for post-conflict reconstruction and long-term competitiveness. Moreover, the Ukrainian experience contributes valuable insights to global discourse on crisis-responsive customs administration. As the country moves toward recovery, sustaining and refining these innovations will be essential for building a resilient economic architecture. In sum, customs policy has become a linchpin of Ukraine's economic security, demonstrating that flexibility, foresight, and strategic alignment are indispensable in navigating complex emergencies.

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Fedyk O. V. Ph.D. of Economics, Department of Management and territorial development named after Yevhen Khraplyvyi, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv (Ukraine)

ORCID – 0000-0002-5996-2103
Researcher ID – KBC-6808-2024
Scopus author id: –
E-Mail: olgafedyk@ukr.net

FORMATION AND IMPLEMENTATION OF THE INNOVATION STRATEGY FOR THE DEVELOPMENT OF AGRICULTURAL ENTERPRISES IN UKRAINE

Olha Fedyk. "Formation and implementation of the innovation strategy for the development of agricultural enterprises in Ukraine". *The article examines the theoretical foundations and practical aspects of developing an innovation strategy for Ukrainian agricultural enterprises in the context of globalization and integration into the European economic space. It substantiates the necessity of systematically introducing technological, organizational, financial, and marketing innovations as decisive factors in ensuring the competitiveness and sustainability of the agrarian sector. The study emphasizes that an innovation strategy should be viewed as a comprehensive system of managerial decisions and coordinated measures aimed at modernizing the material and technical base of enterprises, optimizing resource use, enhancing productivity, and introducing new mechanisms of business management adapted to global challenges.*

Special attention is devoted to technological innovations, including the adoption of precision farming practices, automation of production processes, the use of sensor systems, unmanned aerial vehicles, and advanced biotechnologies. These tools not only increase yields and product quality but also contribute to reducing environmental pressures and achieving more sustainable agricultural development. Organizational innovations are highlighted as an essential dimension of strategic modernization. The establishment of agricultural clusters, cooperatives, and partnerships with research institutions generates synergetic effects, improves the dissemination of knowledge and technologies, and fosters a higher level of innovation culture within enterprises.

Financial innovations are analyzed as a prerequisite for the implementation of modernization projects. Access to grant programs, governmental support instruments, and private or foreign investments provides the financial stability required to introduce advanced technologies, diversify risks, and ensure resilience in conditions of economic fluctuations. Equally significant are marketing innovations, which represent the final stage of implementing an innovation strategy. They encompass branding, positioning on international markets, the use of digital trading platforms, and direct-to-consumer channels, all of which enhance the effectiveness of sales, strengthen product identity, and facilitate successful integration into the highly competitive European and global agrifood markets.

The article proposes a structural and logical framework for developing an innovation strategy, which includes the diagnosis of the internal condition of enterprises, comprehensive analysis of the external environment, identification of innovation priorities, formulation of a detailed strategic plan, and the establishment of a monitoring and evaluation system to ensure adaptability and continuity of the strategy. The research demonstrates that the successful implementation of such a strategy contributes not only to improving the competitiveness of enterprises but also to enhancing ecological safety, strengthening economic stability, and accelerating integration into the international agrarian market.

The findings have both theoretical and practical significance. They may be used in further academic research, in the formulation of policy recommendations for improving managerial approaches, in the optimization of financial mechanisms for the agrarian sector, and in the practical introduction of advanced technologies into agricultural production. Ultimately, the article highlights that innovation-driven strategies are not merely a tool for economic modernization but also a pathway for Ukraine to secure a strong position in the global food market while meeting European standards of quality, safety, and sustainability.

***Keywords**:* innovation strategy, agricultural enterprises, technological innovations, organizational innovations, financial innovations, marketing innovations, competitiveness, sustainable development, agrarian sector

Ольга Федик. «Формування та реалізація інноваційної стратегії розвитку агропідприємств України». *У статті розглянуто теоретичні та практичні аспекти формування інноваційної стратегії розвитку агропідприємств України в умовах глобалізації та інтеграції до європейського економічного простору. Обґрунтовано необхідність системного впровадження технологічних, організаційних, фінансових і маркетингових інновацій як ключових чинників забезпечення конкурентоспроможності аграрного сектору. Визначено, що інноваційна стратегія є цілісною системою управлінських рішень і заходів, спрямованих на модернізацію матеріально-технічної бази, оптимізацію використання ресурсів, підвищення продуктивності та формування нових механізмів господарювання. Особлива увага приділена технологічним інноваціям, зокрема впровадженню точного землеробства, автоматизації виробничих процесів, використанню сенсорних систем, безпілотних апаратів і біотехнологій, що дозволяють підвищити врожайність, якість продукції та знизити екологічне навантаження. Розкрито роль організаційних інновацій, спрямованих на створення аграрних кластерів, кооперативів і партнерств із науковими установами, що забезпечують синергійний ефект та сприяють підвищенню рівня інноваційної культури підприємств. Важливе місце займають фінансові інновації, пов'язані із залученням грантових коштів, державної підтримки та інвестицій, які створюють умови для реалізації модернізаційних проєктів і зменшення виробничих ризиків. Маркетингові інновації розглянуто як завершальний етап реалізації інноваційної стратегії, оскільки вони визначають ефективність збуту, вихід на нові ринки, формування бренду та використання цифрових платформ для просування продукції. Запропоновано структурно-логічний підхід до етапів формування інноваційної стратегії, що охоплює діагностику внутрішнього стану підприємства, аналіз зовнішнього середовища, визначення інноваційних пріоритетів, розробку стратегічного плану та систему моніторингу реалізації. Доведено, що успішна реалізація інноваційної стратегії забезпечує підприємствам зростання конкурентоспроможності, підвищення екологічної безпеки, зміцнення економічної стабільності та інтеграцію у міжнародний ринок. Результати дослідження мають як наукове, так і практичне значення та можуть бути використані для розробки рекомендацій з удосконалення управлінських підходів, оптимізації фінансових механізмів і впровадження новітніх технологій у діяльність аграрних підприємств.*

Ключові слова: інноваційна стратегія, агропідприємства, технологічні інновації, організаційні інновації, фінансові інновації, маркетингові інновації, конкурентоспроможність, сталий розвиток, аграрний сектор.

The relevance of the problem. The contemporary development of Ukraine's agricultural sector is taking place under conditions of increasing competition in global markets, intensifying climate challenges, and the urgent necessity of integration into the European economic area. Traditional approaches to production organization are gradually losing their effectiveness, as they no longer ensure a sufficient level of competitiveness and stability for agricultural enterprises. Under these circumstances, innovation emerges as the key factor in enhancing productivity, product quality, and environmental safety of agricultural production. The formation of an innovative development strategy enables enterprises not only to modernize their material and technical base and introduce advanced technologies, but also to develop modern forms of management, financing, and marketing. At the same time, an orientation toward sustainable development and compliance with European standards creates opportunities for strengthening Ukraine's position as one of the leading producers of agricultural products in the world. Therefore, research into the process of forming an innovative development strategy for agricultural enterprises is of exceptional relevance both in theoretical and practical dimensions.

An analysis of the latest research. The problem of forming and implementing innovation strategies in the agricultural sector of Ukraine has attracted considerable attention from domestic scholars in recent years. Nehoda and Novak (2023) emphasize the importance of innovation support for the agrarian sector, arguing that systematic implementation of technological and organizational innovations is a decisive factor in ensuring competitiveness and sustainable growth. Similar ideas are developed by Lutsii and Korniichuk (2022), who explore the peculiarities of shaping innovation development strategies for agricultural enterprises, highlighting the role of managerial approaches and resource optimization.

Breus and Dudnyk (2023) investigate the role and significance of innovations in the formation of development strategies for agro-industrial enterprises. Their research underlines that innovative tools not only modernize production processes but also create new opportunities for strategic positioning in both domestic and international markets. A more comprehensive approach is presented by Sus, Yemets, Movchun, Onyshko, and Tsiupa (2022), who focus on the formation of innovation strategies at the sectoral level. They pay particular attention to financial mechanisms for implementing innovations, including the use of state support, grant programs, and investment resources.

Taken together, these studies form a solid scientific foundation for understanding the structural components and practical mechanisms of innovation strategies in Ukraine's agrarian sector. At the same time, they point to the need for a holistic and integrated approach that combines technological, organizational, financial, and marketing innovations, ensuring long-term competitiveness and sustainable development of agricultural enterprises in the context of globalization and European integration.

Formulation of the purpose of the study. The purpose of this study is to provide a theoretical justification and a practical analysis of the process of forming an innovative development strategy for agricultural enterprises in Ukraine. Particular attention is devoted to identifying the structural elements of the innovation strategy and their interrelations, assessing the impact of technological, organizational, financial, and marketing innovations on improving the efficiency of agricultural production, as well as substantiating the role of innovation in ensuring competitiveness and sustainable development of the agrarian sector. An important objective is to develop methodological foundations for designing an innovation strategy that takes into account both the internal capabilities of enterprises and the external conditions of their functioning. Achieving this purpose will make it possible to create a comprehensive model of innovative development for agricultural enterprises, capable of ensuring their economic stability, environmental safety, and integration into the European and global markets.

Presentation of the main research. The results of our research demonstrate that an innovative development strategy for agricultural enterprises represents an integrated system of long-term managerial decisions and practical measures that ensure the renewal and improvement of agricultural production. This strategy involves not only the introduction of modern technologies and the modernization of the material and technical base, but also the application of new approaches to labor organization, resource and financial management. An important aspect of such a strategy is the development of effective product distribution channels, the use of digital tools for monitoring and planning, as well as the establishment of agricultural clusters and cooperatives.

Particular significance is attached to the orientation toward environmental safety and sustainable development, which aligns with European standards and opens opportunities for integration into the international market. As a result of implementing an innovative strategy, enterprises are able to enhance their competitiveness, reduce production risks, and ensure long-term economic stability.

Today, Ukraine's agricultural sector faces the dual challenge of not only maintaining its position as one of the world's leading producers of agricultural products but also advancing toward deeper integration into the European market, improving productivity, and strengthening the environmental safety of production. These objectives cannot be achieved without the systematic implementation of innovations encompassing technological, organizational, financial, and marketing dimensions of enterprise activity (Fig. 1).

Technological innovations in agriculture play a leading role, as they form the foundation of modern production. This primarily concerns the implementation of precision farming, which is based on the use of GPS navigation, unmanned aerial vehicles, sensor systems, and specialized software. Such technologies make it possible to apply fertilizers and crop protection products in a differentiated manner, optimize the use of machinery and energy resources, and reduce the environmental burden on soils. Process automation contributes to minimizing the human factor in production and increasing labor productivity, while biotechnology enables the development of new plant varieties and hybrids resistant to climate change and diseases [3]. Taken together, these measures enable agricultural enterprises to significantly improve both crop yields and product quality.

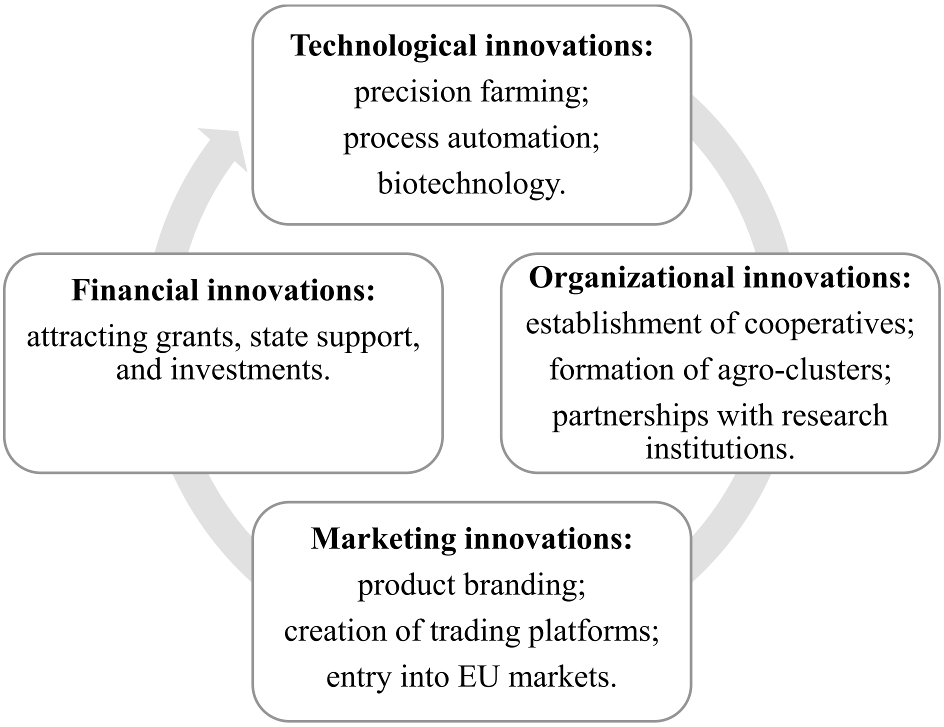

Figure 1 – Structural elements of the innovation strategy for the development of agricultural enterprises in Ukraine

Organizational innovations concern the improvement of management and governance models in the agricultural sector. One of the important directions is the establishment of cooperatives, which allows small and medium-sized producers to pool resources, reduce costs, and enhance the efficiency of product distribution. The formation of agro-clusters fosters the integration of enterprises of different levels and specializations into a single production and distribution chain, thereby generating a synergistic effect. Of particular importance is cooperation with research institutions, which provides enterprises with access to advanced technologies and scientific developments. This raises the level of innovation culture within agribusiness and stimulates the implementation of modern management practices.

Financial innovations represent a necessary condition for the adoption of any novelty in agriculture. The attraction of grants, state support, and investments ensures stable financing for projects associated with production modernization. This is particularly relevant for small and medium-sized enterprises, which often lack sufficient financial capacity to implement advanced technologies. Investment resources make it possible to purchase new machinery, introduce automation systems, develop infrastructure, and enhance export potential. Equally important is the diversification of funding sources, which reduces risks and increases the resilience of enterprises to economic crises.

Marketing innovations constitute the final stage in the implementation of the innovation strategy. Under conditions of intense competition in both domestic and international markets, marketing largely determines the success of product sales. One of the key directions is branding, which creates a unique product identity and increases consumer recognition. The development of modern trading platforms provides enterprises with direct access to consumers, reducing dependence on intermediaries. Particularly significant is entry into the European Union markets, where high requirements for product quality, certification, and safety prevail. For Ukrainian enterprises, this is not only a challenge but also a strong incentive to raise production standards and adapt to international norms.

All these components of the innovation strategy form an integrated system of development in which each element reinforces the others. Technological innovations are impossible without adequate financing, organizational changes facilitate more efficient use of investment resources, and marketing innovations ensure the effective commercialization of products manufactured with advanced technologies. Thus, the innovation strategy serves as the foundation for the sustainable development of agriculture, the enhancement of its competitiveness, and the strengthening of the country's economic stability.

The adoption of innovations in Ukrainian agricultural enterprises carries not only economic but also social significance. The introduction of modern technologies contributes to increased employment in rural areas, the formation of a new production and consumption culture, and the strengthening of food security. Ukraine, with its significant agricultural potential, has the capacity to become one of the global leaders in food production; however, this is achievable only under the condition of systematic and comprehensive innovation implementation.

Therefore, the structural elements of the innovation strategy for the development of agricultural enterprises encompass a wide range of measures: from technological re-equipment and organizational improvement to financial support and marketing advancement. Their coordinated implementation is the key to establishing a modern and competitive agricultural sector capable of functioning effectively under conditions of globalization and integration into the European economic space.

In today's context of globalization and the rapid spread of technological innovations, agriculture faces the necessity of adopting new approaches to the organization of production processes. Growing demand for environmentally friendly products, intensified competition in domestic and international markets, and climate-related challenges make innovation the key factor in enhancing the efficiency of agricultural enterprises. In this regard, the process of forming an innovation-driven development strategy acquires particular significance, as it defines the long-term orientations of enterprise functioning, ensures the rational use of resource potential, and strengthens their competitiveness [1].

The innovation strategy is a system of managerial decisions aimed at implementing technological, organizational, and product innovations in the production and commercial activities of an enterprise. It ensures the formation of an integrated development model that combines traditional management methods with modern advances in science and technology [4].

The theoretical foundations of developing an innovation strategy are based on the necessity of considering both the internal capabilities of an enterprise and the external conditions of its operation. The combination of these factors provides the basis for selecting optimal development directions and shaping long-term competitive advantages [2].

Figure 2 presents the structural and logical framework of the stages of forming an innovation strategy for the development of agricultural enterprises, which is based on the comprehensive consideration of internal and external factors influencing agricultural production.

DIAGNOSIS OF THE INTERNAL STATE OF THE ENTERPRISE

- *analysis of resources, technical support, and human capital*

ASSESSMENT OF THE EXTERNAL ENVIRONMENT

- *study of the market, demand, competitors, and national and international support programs*

SELECTION OF INNOVATION PRIORITIES

- *precision agriculture (GPS navigation, sensors, drones);*
- *biotechnologies (organic fertilizers, biological crop protection);*
- *development of agrotourism and local brands;*
- *implementation of green energy (biogas plants, solar panels).*

DEVELOPMENT OF A STRATEGIC ACTION PLAN

- *scheduling, budgeting, and assignment of responsible persons*

MONITORING AND CONTROL

- *systematic evaluation of strategy implementation effectiveness*

Figure 2 – The process of formulating the innovation development strategy for agricultural enterprises in Ukraine

The first and highly important stage in the process of formulating an innovation strategy is the diagnosis of the enterprise's internal state. At this stage, a comprehensive analysis of available resources, the level of technical provision, the condition of material and technical infrastructure, and human capital is conducted. Particular attention is paid to identifying the enterprise's strengths and weaknesses, determining its strategic reserves, and identifying opportunities to enhance operational efficiency. The SWOT analysis method is frequently employed for this purpose, as it allows for the systematic organization of information on the enterprise's internal characteristics and their correlation with external threats and opportunities. This approach provides a more complete understanding of the enterprise's strategic position and forms the basis for a well-founded selection of innovation priorities.

The next step involves assessing the external environment, since the activities of an agricultural enterprise largely depend on market dynamics. The analysis covers trends in demand for agricultural products, the level of competition, changes in consumer preferences, as well as government policies supporting agribusiness. International programs play a significant role as well, providing access to investment resources and advanced technologies, while also creating opportunities for integrating Ukrainian enterprises into global agricultural value chains. A thorough study of the external environment makes it possible to identify those areas of innovation activity that will yield the greatest effect, considering existing constraints and future prospects.

Based on the results of internal and external diagnostics, a system of innovation priorities is formed. For modern agricultural enterprises, promising areas include precision agriculture, which relies on GPS navigation, sensor systems, and unmanned aerial vehicles to increase the accuracy and efficiency of agrotechnical operations; the application of biotechnologies, including the production of organic fertilizers and biological plant protection products; the development of agrotourism and the creation of local brands as tools for business diversification; and the implementation of renewable energy sources, such as biogas plants and solar panels, which reduce energy costs and enhance the enterprise's environmental image. The selection of specific priorities is carried out taking into account resource availability, financial capacity, and the enterprise's strategic goals.

The next stage involves the development of a strategic action plan, within which the selected areas of innovation development are detailed. The plan includes scheduling of activities, budget preparation, identification of funding sources, and the allocation of functional responsibilities among structural units and individual performers. The effectiveness of this stage largely depends on the quality of managerial decisions, coordinated teamwork, and the presence of motivational mechanisms capable of encouraging staff to actively implement innovations. An important task is also the establishment of a risk management system, as innovation activities are inherently accompanied by uncertainty and require flexible responses to changes in external and internal conditions.

The final stage of the process is the monitoring and control of the innovation strategy implementation. This involves systematically tracking the results of planned activities, assessing the degree to which objectives are achieved, and timely identification of deviations. Monitoring is conducted both through quantitative indicators, such as productivity, profitability, and production costs and qualitative criteria, including the level of environmental safety, consumer satisfaction, and the enterprise's market image. The results obtained serve as a basis for strategy adjustments, ensuring its adaptability and capacity to respond to changing operational conditions.

Thus, the process of formulating an innovation development strategy for agricultural enterprises is multi-stage and systematic. It encompasses the diagnosis of the enterprise's internal state, assessment of the external environment, determination of innovation development priorities, formulation of a strategic action plan, and organization of effective monitoring and control. The proposed approach allows agricultural enterprises to combine traditional production practices with modern technologies, creating the prerequisites for enhanced competitiveness and sustainable development. In the long term, an innovation strategy will become a key factor in integrating the Ukrainian agricultural sector into the global economic space.

Conclusions. The innovation development strategy for agricultural enterprises in Ukraine emerges as a comprehensive system of managerial decisions and measures aimed at modernizing agricultural production, enhancing its competitiveness, and increasing resilience to the challenges of the global environment. It integrates technological, organizational, financial, and marketing innovations, which complement each other to form a unified development model. The implementation of precision agriculture, automation of production processes, biotechnologies, and digital tools enables the rational use of resources, improves productivity, and reduces environmental risks. Organizational changes, such as cooperation and the creation of agro-clusters, ensure synergy among producers, science, and the market, while financial instruments, including investments and grants, provide new opportunities for the development of even small and medium-sized enterprises. At the same time, marketing innovations focused on branding and entering international markets allow Ukrainian enterprises to establish themselves within the European economic space.

Thus, the innovation strategy carries not only economic but also social significance: it contributes to increased employment in rural areas, the formation of a new culture of production and consumption, and the strengthening of food security. Its comprehensive implementation lays the foundation for sustainable development of the agricultural sector, ensures adaptability to contemporary challenges, and opens up prospects for Ukraine's integration into the global food market.

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Bugayko D. O. Doctor of Science (Economics), Professor, Academician of the Academy of Economic Sciences of Ukraine, Corresponding Member of the Transport Academy of Ukraine, Vice - Director of ES International Cooperation and Education Institute, Instructor of ICAO, Professor of the Logistics Department, Leading Researcher, State University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0000-0002-3240-2501
Researcher ID – ABF-5564-2021
Scopus author id: – 57216582348
E-Mail: bugaiko@kai.edu.ua

Hryhorak M.Yu. Doctor of Sciences (Economics), Professor (Associate), Academician of the Academy of Economic Sciences of Ukraine, Professor of Department of International Business and Logistics of National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0002-5023-8602
Researcher ID – AAK-2963-202
Scopus author id: – 57208222758
E-Mail: hryhorak.mariia@lll.kpi.ua

Katsman M.D. Doctor of Sciences (Technical), The Joint-Stock Company of Railway Transport of Ukraine "Ukrzaliznytsia" (Ukraine)

ORCID –
Researcher ID –
Scopus author id: –
E-Mail: mdkatsman@gmail.com

Zaporozhets O.I. Doctor of Sciences (Technical), Professor, Professor of Institute of Aviation (ILot) (Warsaw, Poland)

ORCID – 0000-0002-7580-0921
Researcher ID – E-4449-2019
Scopus author id: – 7003591678
E-Mail: Oleksandr.Zaporozhets@ilot.lukasiewicz.gov.pl

Borysiuk A.V. Postgraduate Student, State University "Kyiv Aviation Institute" (Ukraine)

ORCID – 0009-0005-8790-5797
Researcher ID –
Scopus author id: –
E-Mail: 8390621@stud.kai.edu.ua

CHALLENGES OF POST-WAR SUSTAINABLE DEVELOPMENT OF UKRAINE - EU METALLURGICAL PRODUCTS SUPPLY CHAINS

Dmytro Bugayko, Mariia Hryhorak, Mykhaylo Katsman, Oleksandr Zaporozhets, Anton Borysiuk. "Challenges of Post-War Sustainable Development of Ukraine - EU Metallurgical Products Supply Chains". *In the context of the current transformation of the global economy, the concept of sustainable supply chains is gaining strategic importance for countries from both the demand and supply sides. The European Union, having announced a course to achieve climate neutrality by 2050 and implementing the European Green Deal, has significantly strengthened the requirements for imported products, including requirements for environmental, social and economic sustainability components at all stages of the supply chain. Metallurgical products, in particular steel and semi-finished products, are a basic component of many strategic sectors of the EU economy - construction, mechanical engineering, transport and energy infrastructure. At the same time, steel production is one of the largest sources of greenhouse gas emissions in industry, which necessitates increased attention to the sources of supply and characteristics of metallurgical products in terms of their carbon footprint and compliance with sustainable development standards. The article is devoted to the development of regulatory requirements and the determination of prospects for the integration of sustainable supply chains of metallurgical products from Ukraine to the EU in the post-war period.*

Keywords: supply chains, sustainable development, metallurgical products, green logistics, transport

Дмитро Бугайко, Марія Григорак, Михайло Кацман, Олександр Запорожець, Антон Борисюк. «Виклики післявоєнного сталого розвитку ланцюгів постачань металургійної продукції Україна - ЄС». *У контексті сучасної трансформації світової економіки концепція стійких ланцюгів поставок набуває стратегічного значення для країн як з боку попиту, так і з боку пропозиції. Європейський Союз, оголосивши курс на досягнення кліматичної нейтральності до 2050 року та реалізувавши Європейський зелений курс, значно посилив вимоги до імпортної продукції, включаючи вимоги до екологічних, соціальних та економічних складових стійкості на всіх етапах ланцюга поставок. Металургійна продукція, зокрема, сталь та напівфабрикати, є базовим компонентом багатьох стратегічних секторів економіки ЄС – будівництва, машинобудування, транспортної та енергетичної інфраструктури. Водночас, виробництво сталі є одним з найбільших джерел викидів парникових газів у промисловості, що вимагає посиленої уваги до джерел постачання та характеристик металургійної продукції з точки зору її вуглецевого сліду та відповідності стандартам сталого розвитку. Статтю присвячено розвитку регуляторних вимог та визначенню перспектив інтеграції сталих ланцюгів постачань металургійної продукції з України до ЄС у повоєнний період.*

Ключові слова: ланцюги поставок, сталий розвиток, металургійна продукція, зелена логістика, транспорт.

Introduction. Therefore, for the EU, the relevance of forming sustainable supply chains is explained by several key factors:

1. Decarbonization of the EU economy and industry, which is impossible without the involvement of raw materials and materials with a low carbon footprint.

2. Ensuring strategic autonomy and reducing dependence on unstable or risky sources of supply.

3. Implementation of regulatory initiatives, such as the Carbon Border Adjustment Mechanism (CBAM) and the Corporate Due Diligence Directive (CDRDD), which create a legislative framework for controlling the sustainability of supply chains.

On the other hand, for Ukraine, the issue of sustainable supply chains is not only an external challenge, but also an opportunity for strategic economic integration and strengthening its own competitiveness. Ukraine has historically been a significant supplier of metallurgical products to the EU, and despite the negative impact of the war, it remains an important player in the market of raw materials and semi-finished products. In addition, geographical proximity, the presence of its own iron ore resource base, political rapprochement with the EU and the desire for post-war economic recovery make integration into sustainable supply chains not only expedient, but also a necessary condition for the preservation and development of Ukrainian export potential.

In general, sustainable supply chains are relevant for both the EU and Ukraine due to the combination of the following strategic factors:

- the global trend towards decarbonization and greening of the economy;
- the EU's need to diversify sources of supply of metallurgical products;
- Ukraine's desire to maintain its position in the EU market and adapt to new regulatory requirements;
- a mutual interest in the development of transparent, reliable and sustainable supply chains that meet the principles of sustainable development, social responsibility and environmental safety.

Thus, the sustainable nature of metallurgical supply chains is not only a pressing challenge for Ukraine and the EU, but also one of the key tools for ensuring economic sustainability, energy security, and climate-neutral development of both sides.

The purpose of the article. To analyze the challenges, regulatory requirements and prospects for the formation of sustainable supply chains of metallurgical products between Ukraine and the European Union in the context of the post-war reconstruction of the Ukrainian economy.

Research objectives:

1. To identify the theoretical foundations of the concept of sustainable supply chains and their specifics in the metallurgical industry.

2. To consider the main EU regulatory initiatives that affect the sustainable export of metallurgical products from Ukraine (in particular, CBAM and CDRDD).

3. To analyze the main challenges of the post-war period that affect the formation of sustainable supply chains of metallurgical products.

4. To investigate the logistical aspects of sustainable supply chains and their role in increasing the competitiveness of Ukrainian metallurgy in the European market.

5. To assess the prospects for Ukraine's integration into the EU's green supply chains and to offer recommendations for their development in the context of post-war reconstruction.

Literature Review. The literature review shows that the consequences of aggression against Ukraine are felt in all sectors of the economy, but most of all in export-oriented industries. In this regard, the issue of post-war recovery of the Ukrainian economy and ensuring its competitiveness is attracting increasing attention from researchers. Scientific works [1-2] emphasize that the recovery of the national economy is inextricably linked to the tasks of sustainable development, as well as the possibilities of attracting external financing for the implementation of "green" projects. Considerable attention is paid to the issues of infrastructure modernization, the introduction of energy-efficient technologies into industry, and the development of innovative production practices [3]. Researchers [4] emphasize that the economies of Ukraine and the EU countries have a high level of interdependence, which necessitates the need for post-war reconstruction on the basis of integration into the European economic space. In particular, the literature emphasizes achieving the goals of the circular economy, including legal, economic, and organizational mechanisms for managing recovery processes. Some authors [5, 6] draw attention to the role of legal regulatory instruments and environmental standards that should contribute to the synchronization of Ukrainian economic policy with the European one.

A special place in the review of scientific publications is occupied by studies devoted to the metallurgical industry, which is one of the leading export-oriented sectors of the Ukrainian economy. The works [7, 8] note that increasing the competitiveness of metallurgy is a strategic task for both the state and business. The authors emphasize that effective reconstruction is possible provided that the institutional capacity of the government is strengthened in coordinating decarbonization policies and developing dialogue between industry, business and society.

In modern literature, there is also interest in the potential role of Ukraine as a key supplier of iron ore suitable for the production of direct reduction iron (DRI). Researchers [9, 10.] predict that in the conditions of decarbonization of the metallurgical sector of Europe, the demand for such products will grow. At the same time, the works [11] emphasize that in order to realize this potential, it is necessary to transition to open innovation models that will allow integrating Ukrainian enterprises into global value chains and provide access to international technologies and financial resources.

A separate layer of research focuses on the issue of forming sustainable supply chains for metallurgical products. Scientists [12, 13] emphasize that ensuring reliability and diversification of supplies is of strategic importance not only for Ukraine, but also for the EU, which seeks to reduce dependence on individual markets.

Despite the presence of a significant number of publications devoted to the issues of post-war reconstruction and the prospects for the development of Ukrainian metallurgy, a literature analysis demonstrates the presence of research gaps. The aspects of the organization and functioning of sustainable supply chains for metallurgical products from Ukraine to EU countries in the context of rebuilding the economy on the principles of sustainable development remain insufficiently studied. It is precisely this issue that requires further thorough scientific research.

Presentation of the main results. Theoretical foundations of sustainable supply chains for metallurgical products. Sustainable (green) supply chains in the metallurgical industry have a number of features, which are due to both the specifics of the industry itself and high expectations for the decarbonization of the industry on a global scale. Metallurgy is one of the most energy- and resource-intensive sectors of the economy, where production processes are accompanied by significant greenhouse gas emissions, high water consumption, the use of fossil fuels and the generation of waste. According to international studies, metallurgy accounts for 7–9% of global CO_2 emissions, which makes this industry one of the key targets of the "green transition" policy in the European Union and other regions of the world. In this context, sustainable supply chains of metallurgical products are characterized by a complex multi-level structure, which includes such elements as extraction and transportation of raw materials (iron ore, coal, scrap), production processes (processing, smelting, rolling), logistics of finished products, as well as recycling and reuse of metal. A feature is that a negative environmental footprint is formed not only at the stage of steel production, but also at the stage of transportation and supply, which is especially relevant for Ukraine, given the complex geography of supplies to EU countries.

An important characteristic of sustainable supply chains in metallurgy is the need to implement the latest "green" technologies, such as electrometallurgy based on renewable energy, the use of hydrogen instead of carbon for iron recovery processes (DRI - Direct Reduced Iron technology), closed water supply cycles, effective waste management and an increase in the share of secondary raw materials - scrap metal. Therefore, manufacturers seeking to remain competitive in EU markets must not only declare sustainability, but also prove it through product certification, supply chain transparency and compliance with European initiatives such as the Green Deal, CBAM and CDRDD.

In addition, supply chains in the metallurgy industry are often international and include a large number of participants - from suppliers of raw materials to end users of finished products in mechanical engineering, construction and other industries. This leads to high requirements for coordination, information transparency and corporate responsibility standards. This is especially relevant for Ukrainian metallurgy, which is focused on exports, in particular to the European Union, where consumers are increasingly paying attention not only to quality and price, but also to the environmental and social footprint of products.

Thus, the peculiarity of sustainable supply chains in metallurgy is their complexity, resource and energy intensity, dependence on geographical and logistical factors, as well as the critical need for modernization of technologies and implementation of international standards of sustainable development to maintain competitiveness in global markets.

The EU regulatory environment and its impact on sustainable exports of Ukrainian metallurgy. The analysis of the EU regulatory environment shows that over the past decade the concept of sustainable supply chains has transformed from a corporate initiative of individual companies into a mandatory regulatory standard, which is increasingly being applied at the interstate level. The European Union regulatory environment in the field of sustainable supply chains is one of the most progressive in the world and has a direct impact on supplier companies from third countries, in particular from Ukraine.

The foundation of modern European policy in this area is the European Green Deal initiative, adopted in 2019, which envisages the transition of the EU to a climate-neutral economy by 2050 [14]. According to this strategy, all sectors of the economy, including industry and international trade, should transform their supply chains to reduce their carbon footprint, increase energy efficiency and ensure social responsibility. One of the key regulatory mechanisms of the Green Deal, which directly affects the supply chains of metallurgical products, is the Carbon Border Adjustment Mechanism (CBAM), which began operating in a test mode in October 2023 [15]. The CBAM provides for the gradual introduction of an import levy on products with a high carbon footprint, including steel, iron, cement, fertilizers and other goods. The main goal of this mechanism is to protect European producers from "carbon leakage" and to encourage EU partners to modernize their production processes in accordance with environmental standards. For Ukrainian metallurgical enterprises, this means the need to ensure transparent accounting of CO2 emissions at all stages of production in order to maintain access to the European market on competitive terms. Another important element of the regulatory environment is the CDRDD - the EU Directive on Corporate Sustainability Due Diligence, which was finally agreed in 2024 [16]. It establishes an obligation for large companies operating in the EU market to carry out a comprehensive check of the sustainability of their supply chains, including environmental, social and human rights aspects. The directive applies not only to European companies, but also to their suppliers from third countries. Thus, Ukrainian steel companies that want to remain in the supply chains of leading European manufacturers must confirm compliance with environmental standards, principles of social responsibility, human rights and labor standards at all stages of the production process [17].

The combination of regulatory initiatives such as the Green Deal, CBAM and CDRDD creates new rules of the game for international supply chains, where sustainable development, decarbonization and transparency become not a competitive advantage, but a prerequisite for participation in the European market. For Ukraine, this is not only a challenge, but also an opportunity to integrate into the EU's strategic green chains, provided that the national industry adapts, introduces modern environmental technologies and builds transparent, responsible supply chains for metallurgical products [18, 19].

For several years now, Ukraine has been actively discussing how the EU regulatory environment could affect the development of the metallurgical industry and its export potential. In particular, in October 2024, GMK center published a report "How the European SBAM could weaken the Ukrainian economy" [20], which concluded that the Ukrainian metallurgical industry will suffer the most from CBAM, since 93% of Ukrainian exports covered by CBAM are iron and steel products. CBAM will lead to a gradual reduction in free allowances in the EU ETS system. For example, in 2026, it is planned to cancel 2.5% of free allowances, in 2030 - 48.5%, and in 2034 - 100%. A reduction in free allowances will lead to an increase in carbon prices in the EU ETS and an increase in CBAM payments. The higher the CBAM costs, the greater the losses for the Ukrainian economy. Due to the European CBAM, Ukraine may stop exporting cement, fertilizers, cast iron, square billets and long products after 2030. In this case, export losses will exceed $1.4 billion, of which losses in exports of MMC products will amount to $1.3 billion. According to revised estimates for the current year, potential investment losses in the Ukrainian economy in 2026-2030 may amount to $2.7 billion, and potential losses from exports during this period will amount to $4.7 billion [21]. GDP losses will be even greater due to inter-sectoral linkages in the Ukrainian economy. For example, the metallurgical sector affects the activities of the coal and coke chemical industries, mechanical engineering and the service sector. The metallurgical industry is a key driver of development in the regions where production facilities are located.

There is no doubt that the Russian invasion and the resulting damage to Ukraine meet the conditions of Article 30.7 of the Regulation. The Russian invasion, while being beyond Ukraine's control, has caused significant and devastating consequences for economic and industrial infrastructure. Direct losses alone as of early 2024 amounted to $155 billion. Losses are increasing with each passing day of the war. This time has been lost in adapting Ukraine's economy to the goals of the "green" transition. In addition, Ukraine will have limited opportunities to stimulate decarbonization in the post-war period. Excluding Ukraine from the CBAM under Article 30.7 is a logical step and will be a test for the mechanisms envisaged by European legislators in regulating the CBAM.

Ukrainian industry experts believe that Ukraine should take advantage of the provisions of Article 30.7 of Regulation (EU) 2023/956 of the European Parliament and of the Council of 10.05.2023, on the exclusion of third countries from obligations under the CBAM The Russian invasion, being beyond the control of Ukraine, has caused significant destructive consequences for the economic and industrial infrastructure. According to Reuters, as of February 2025, direct losses to Ukraine from Russian aggression are estimated at $176 billion. This amount includes direct physical destruction of buildings and infrastructure, as well as the impact on the lives and livelihoods of citizens. Losses are growing with each passing day of the war, which has been going on for 2 years and 7 months at the time of this report. This time has been lost to adapt Ukraine's economy to the goals of the "green" transition. In addition, in the post-war period, Ukraine will have limited opportunities to stimulate decarbonization. Excluding Ukraine from the CBAM under Article 30.7 is a logical step and will be a test for the mechanisms envisaged by European legislators in regulating CBAM. Table 1 summarizes the impact of CBAM and CDRDD on the Ukrainian metallurgical industry.

Table 1 – Impact of CBAM and CDRDD on the metallurgical industry of Ukraine

Aspect	CBAM (Carbon Border Adjustment Mechanism)	CDRDD (Corporate Sustainability Due Diligence Directive
Opportunities		
1. Incentive for modernization and reduction of carbon footprint	Increasing the technological level of the industry to comply with EU requirements	Motivation for increased transparency, environmental and social responsibility
2. Access to the "green" European market	Maintaining and potentially expanding market share for "green" steel producers	Priority for responsible suppliers in the supply chains of European companies
3. Attracting investments and technologies	Chance to receive EU funding for decarbonization	Possibility to attract partnership programs and investments to improve sustainability standards
4. Deepening integration with the EU	Compliance with European climate legislation	Harmonization with EU social and environmental standards, bringing the economy closer to the EU
Threats		
1. Financial losses for non-competitive producers	Increasing export costs through carbon payments for high-CO^2 companies	Potential loss of contracts for companies that do not provide adequate transparency
2. Risk of reduced exports	Losing positions in the EU market without modernization	Exclusion from European supply chains due to non-compliance
3. Administrative burden	Need to introduce carbon footprint accounting systems	Implementation of a system of monitoring, auditing, verification of suppliers |
4. Increasing competitive pressure	Increasing competition from "green" producers from other regions	European companies can choose suppliers from countries with a better reputation in the field of sustainability

Source: compiled by the authors

An important component of the European Union's current regulatory policy in the field of sustainable development is the requirement for the introduction of Product Digital Passports (PDP), which increasingly cover industrial goods, in particular products from the metallurgical sector [22]. This tool is part of a broader EU initiative aimed at increasing transparency, environmental responsibility and traceability of supply chains in line with the objectives of the European Green Deal and the Sustainable Products Package. The issue of digital passports is most systematically enshrined in the draft EU Regulation on Ecodesign for Sustainable Products (ESPR), the adoption of which is expected in the coming years. Under the ESPR, a digital passport will be mandatory for certain product categories, including steel, aluminium and other industrial materials, containing detailed information on the origin of the raw materials, product characteristics, carbon footprint, environmental and social aspects of production, and recycling and reuse options.

In addition, the provisions on supply chain transparency and mandatory disclosure of environmental impact are contained in the Corporate Sustainability Due Diligence Directive (CSDDD or CDRDD). It explicitly requires large companies and their suppliers, including those from third countries, to demonstrate compliance with environmental and social standards at all stages of the production and logistics process, which requires the provision of supporting documents, among which digital product passports are becoming one of the key tools [23]. In the context of metallurgical products, this means that Ukrainian manufacturers seeking to maintain or expand their presence on the European market should prepare today to implement digital passports for their products. This requires modernization of information systems, implementation of internal carbon footprint monitoring, transparent declaration of materials used, as well as digital integration with European partners. Thus, digital product passports become not only a regulatory requirement, but also a strategic element in the formation of sustainable supply chains, which ensures transparency, increases trust in Ukrainian metallurgical products and creates additional competitive advantages on the European market.

Post-war challenges for sustainable supply chains of Ukrainian steel products. The Ukrainian economy is traditionally export-oriented. During the war, the EU became the main trading partner, given the blockade of Ukrainian seaports. Exports allow Ukrainian companies to continue production activities, support employment and the local economy. The steel industry is traditionally one of the key export-oriented industries of Ukraine, providing a significant share of foreign exchange earnings, employment and industrial production. According to data before the full-scale invasion, more than 80% of Ukrainian steel products were exported to the European Union and other countries, which indicate the deep integration of Ukrainian steel into global and European supply chains.

The mining and metallurgical sector (MMS) has been and remains one of the key sectors of the economy. The numbers speak for themselves. In 2021, MMS accounted for 10% of the country's total GDP. Export revenue was estimated at $22 billion and accounted for ⅓ of total exports. The enterprises employed over 130,000 people and another 530,000 in related industries. UAH 95 billion in direct taxes were paid. The full-scale invasion significantly affected the sector, as a large share of enterprises was located in the eastern regions of the country, which are temporarily occupied. In 2024, its contribution was 7.2% of Ukraine's GDP, including supply chains. In 2024, the sector's share in total exports was almost 15%.

Table 2 presents statistical data on the production volumes of the mining and metallurgical sector of Ukraine.

Table 2. Production volumes of metallurgical products in Ukraine, thousand tons

Product Types	Production volumes, thousand tons			
Years	2021	2022	2023	2024
Iron Ore	84431	31411	28823	44690
Pigment Iron	3236	1325	1249	1290
Steel	21366	6263	6228	7575
Long Rolled Products	3800	1350	1764	2028
Scrap Procurement	4100	997	1277	1749

Source: compiled by the authors based on data from GMK center

In 2024, Ukraine reached a local peak in steel exports (forecast 4.6 million tons), largely due to the growth in supplies of semi-finished products. However, the forecast for 2025 (3.9 million tons) looks less optimistic. In January-May 2025, the mining industry of Ukraine reduced iron ore exports by 12.8% compared to the same period in 2024 - to 13.54 million tons [24].

Most experts predict a further reduction in the production and export of metallurgical products in 2025 due to increasing risks and challenges for the entire mining and metallurgical complex of the country. A particularly significant risk is the decline in square billet exports. In 2024, the disparity between cheaper iron ore and expensive scrap made exports profitable. However, at the end of the year, scrap prices fell due to active exports of billets from China. This may significantly affect Ukraine's export opportunities in 2025. Table 3 summarizes the main influencing factors and key challenges and possible negative consequences that will directly affect the reduction in the volume of production and exports of MMS products.

Table 3 – Main challenges and threats for the metallurgical industry of Ukraine

Factor	Threat/Challenge Essence	Likely consequences
Continued hostilities and stagnation in the domestic market	Destruction of infrastructure, shutdown of enterprises, low domestic demand	Decline in production and investment
Competition with Russian metal in the EU	EU continues to purchase Russian metal products despite sanctions, dumping by the Russian Federation	Loss of Ukrainian exports' share in the EU market
Decrease in world prices due to increased steel exports from China	Oversupply of Chinese products puts pressure on global prices	Decline in profitability of Ukrainian exports
Deficit of coking coal and the need to import coke	Increasing production costs due to dependence on imports	Worsening of product competitiveness
Trade restrictions on the export of Ukrainian metal products (28 barriers)	Quotas, anti-dumping investigations, technical barriers	Limited access to foreign markets
Carbon border tax in the EU (CBAM)	Ukrainian products with a high carbon footprint will be subject to additional duties	Potential losses of up to $1.6 billion annually by 2030
Increase in tariffs of natural monopolies (transportation, electricity, gas, water)	Increasing cost of production	Decline in profitability, risk of closure of some enterprises
Labor shortage (15–20% of personnel mobilized)	Lack of qualified personnel, reduced productivity	Stoppage of certain production processes, slowing down of industry recovery
Complicated logistics and high logistics costs	Longer delivery times, difficulties at borders, high freight rates	Increase in the final cost of products, decrease in competitiveness

Source: compiled by the authors

Among the systemic challenges is the shortage of personnel. Wartime significantly complicated the selection and retention of qualified specialists, especially in areas with physical exertion. Despite this, we see new opportunities - women are actively involved in technical professions and often demonstrate high results. Logistics remains no less critical: extended delivery times, unstable transport costs, difficulties at border crossings.

Additional pressure on manufacturers is also created by increased logistics and energy costs. In particular, Ukrzaliznytsia plans to increase transportation tariffs again. The logistics component in the cost of cargo will increase for coal and ferrous metals - up to 1%. Thus, according to the calculations of ArcelorMittal Kryvyi Rih, the additional costs of the enterprise for logistics will amount to more than UAH 1.4 billion per year, which will reduce the competitiveness of products along the chain and may lead to a complete stoppage of production [25].

Not the least of the challenges is the problem with the supply of coking coal. Most of the domestic supply depends on the Pokrovske mine management, whose work is under threat due to hostilities. If the mine stops, metallurgists will be forced to import more expensive coal, which could significantly affect the cost of production.

Logistics aspect of sustainable supply chains. Logistics is a critically important component in the formation of sustainable supply chains, especially in the metallurgical sector, where a large mass of products, the complexity of transportation and high requirements for maintaining product quality necessitate careful organization of transport and warehousing processes. In the context of Ukraine's post-war reconstruction and increased EU requirements for environmental friendliness and transparency of supply chains, logistics acquires additional strategic importance. Starting in 2022, the war has significantly affected Ukraine's infrastructure and logistics capabilities. In particular, key railway and port facilities were damaged, which led to a decrease in the throughput capacity of transport hubs and the need to look for alternative routes. In addition, logistics costs have increased significantly due to higher fuel prices, complicated customs procedures, increased insurance tariffs and unstable transportation schedules. The main challenges/problems for the logistics aspect of Ukraine's sustainable supply chains are listed in Table. 4.

One of the key challenges for the formation of sustainable supply chains of metallurgical products from Ukraine to the European Union countries remains high logistical vulnerability, which is due to objective limitations of the infrastructure and the insufficient level of its development. In particular, one of the most critical challenges is the concentration of metallurgical product exports through a limited number of available transport corridors. Due to the destruction of port and railway infrastructure in the south and east of Ukraine, as well as the blocking of traditional sea routes, the main export flows are forced to be directed through western land crossings, such as corridors through Poland, Slovakia, Hungary and Romania. This creates "bottlenecks" at border crossing points, which leads to delays, increased costs and reduced predictability of supplies, as well as to an increase in greenhouse gas emissions.

The impact of transport logistics on the carbon footprint of metal products is one of the key criteria for compliance with European sustainability standards. Transport CO2 emissions, especially when using diesel trucks, significantly increase the overall environmental footprint of metallurgical products. To reduce the negative impact, it is advisable to use multimodal transportation, combining rail, river and sea transport, which allows optimizing routes and reducing emissions. In addition, the gradual introduction of electric transport, the use of energy-efficient warehouse solutions and "green" packaging materials creates additional value for end consumers and EU regulators.

EU transport policy is focused on increasing the role of rail transport in the freight transport system. The integration of Ukraine's railway network into the European one involves the expansion of the Eurogauge (1435 mm) to the territory of Ukraine, in particular, on the Kyiv-Kharkiv-Dnipro routes, as well as in the west and south of the country. This includes the extension of the Eurogauge from Rava-Ruska through Lviv to the border with Romania, as well as from Odessa to Chisinau. The implementation of these projects, which are part of the TEN-T network, will allow Ukraine to access financing and promote integration into the European transport system.

In June 2025, the World Bank published a report analyzing the reform of Ukrzaliznytsia, infrastructure modernization and investments in Ukraine's railways - "Ukraine's Transport and Logistics System" [26]. The study covers TEN-T, cross-border logistics, export transportation and the EU integration strategy. This report notes that Ukraine has one of the largest railway networks in Europe - over 19 thousand km, of which approximately 47% is electrified. However, about 60% of the tracks are operated beyond their standard service life, more than 35% of the switches are in unsatisfactory condition.

Table 4. Key challenges/issues for the logistics aspect of sustainable supply chains in Ukraine

Type of transport	Challenges and problems	Solutions
Maritime transport: Capacity 250 million tons per year 2. Provided 70% of the export of agricultural products, metallurgy, chemical industry and mineral fertilizers and 90% of agricultural products	– blockade of seaports by Russia; – destruction of port infrastructure (Odesa, Mykolaiv); – low throughput capacity of Danube river ports (only 10 million tons per year) and passage only for small vessels and barges; – problem of storage and transportation of containers with goods from alternative ports; – low throughput capacity of alternative ports (Constanta, Romania).	– use of the main ports of neighboring countries in Gdansk, Varna, Constanta; – construction of strategic universal transport hubs; – restoration of damaged port infrastructure.
Railway transport: 1. Brought 70-80 billion in revenue annually 2. Transportation was carried out to seaports and within the country 3. 65% of cargo was transported by rail	– 6.3 thousand km of railway network, 41 railway bridges, 21 railway stations were destroyed; – change in freight directions (to seaports changed to the western); – bureaucratic and overly regulated document flow; – the need to protect infrastructure from enemy attacks; – capacity limitations at checkpoints (sorting stations, lack of warehouses, low level of processing) and technological problems of different gauge sizes.	– development of the Eurorail from the Ukrainian side; – increasing the number of checkpoints on the border with EU countries – creation of a single portal for processing transportation documents.
Road transport provided 36% of freight transportation (244 million tons per year)	– rising fuel prices and limited availability; – increasing queues at checkpoints on the western border to 35-50 km; – increasing border crossing time to 7 days; – increasing transportation costs.	– increasing the throughput capacity of automobile checkpoints; – extending the validity of the "Transport Visa-Free"; – introducing "eQueues".

Source: developed by the authors

The war significantly accelerated the physical depreciation of assets: more than 11 thousand damaged railway infrastructure objects were recorded. The level of wear and tear of traction rolling stock and freight wagons remains critically high, which limits the capacity and productivity of the network.

Particularly critical is the lack of specialized rolling stock that is compatible with the European (narrow) gauge. The UZ rolling stock often does not meet EU standards due to differences in dimensions and technical parameters. The report indicates that both UZ and European operators face a shortage of grain trucks, refrigerators and tanks that would meet EU standards. At the same time, due to the uncertainty of future demand, European operators are not ready to invest in increasing the fleet of wagons for cross-border trade with Ukraine. This further limits the ability of rail transport to ensure the export of Ukrainian goods to the EU, especially given the need for rapid transhipment and compliance with European standards.

At the same time, integration into the EU system requires a balanced approach: instead of a massive transition to the standard 1435 mm gauge, it is proposed to develop transhipment capacities and stimulate containerization. The report emphasizes the importance of containerization and the development of multimodal logistics, which is characteristic of the transportation of products with higher added value. This indicates a potential shift in focus from the transportation of raw materials to more complex goods in the export structure. The report also emphasizes the need to reform JSC Ukrzaliznytsia and adapt the industry to the requirements of the European transportation market. In particular, this concerns the New Law "On Railway Transport", which should harmonize Ukrainian legislation with EU law and provides for the separation of infrastructure and transportation management functions.

To increase the sustainability of metallurgical product supply chains, diversification of transport routes is necessary. The use of transport corridors through Poland, Romania, Slovakia, and Hungary opens up alternative export routes, reduces the load on traditional highways, and increases delivery reliability. That is why the development of Danube ports and water transport has special potential, which allows reducing logistics costs and environmental impact.

As noted in the World Bank report, deep-water Black Sea ports will remain the main export-import "gateway" of Ukraine. Despite the development of alternative routes (Danube, roads, and railways), none of them has sufficient reserve capacity to fully replace the Black Sea route in the event of its repeated blocking. Short-term actions should focus on improving multimodal access to ports, restoring railway infrastructure, purchasing new locomotives and modernizing transshipment equipment. Despite their secondary role compared to deep-sea ports, Danube ports remain a strategic reserve and insurance logistics route for Ukraine. They provide an alternative route for exporting large-tonnage cargo over medium and long distances - through direct shipping to the Mediterranean or barge transportation to Constanta with subsequent transshipment onto ocean-going vessels. However, the current infrastructure of Danube ports does not allow for full compensation for the volumes lost in the event of restricted access to the Black Sea.

As GMK Center reported, Ukrainian seaports processed 18.5 million tons of ore cargo in 2024 [vi https://gmk.center/en/news/ukrainian-ports-handled-23-million-tons-of-cargo-in-the-first-quarter-of-2025/]. The total cargo turnover last year reached a record high of 97.2 million tons compared to 62 million tons in 2023, exports amounted to 88.1 million tons. The largest volumes of transshipment traditionally fall on the ports of Greater Odessa, which provided 20.7 million tons of cargo turnover. Another 2.3 million tons passed through the ports of the Danube region - Izmail, Reni and Ust-Dunaysk. In January-June 2025, Ukrainian seaports processed about 40 million tons of cargo, of which more than 9.3 million tons were iron ore products, and another 2.1 million tons were ferrous metals [20, 23]. For comparison: in pre-war 2021, the volume of sea transshipment in Ukraine reached 153 million tons, of which almost 38 million tons were ore cargoes, and 16 million tons were ferrous metals.

An additional factor complicating the supply chains of metal products is the increased complexity of coordination between different modes of transport and numerous participants in the supply chain. The export of metallurgical products usually involves multimodal transportation, including rail, road and sea transport. In conditions of limited capacity of individual infrastructure sections, lack of agreed schedules and insufficient integration between different modes of transport, time and financial costs increase, as well as the risks of violating delivery deadlines. This is especially critical for metallurgical products, which often have large-sized characteristics, require special transportation conditions and fast delivery to maintain competitiveness.

Another systemic problem that significantly limits Ukraine's integration into sustainable supply chains of metallurgical products to the EU is the insufficient level of digitalization of logistics processes and supply chain management. Modern requirements of the European market have long gone beyond the traditional control over the physical movement of goods. Participants in supply chains, especially in such sensitive industries as metallurgy, are expected to have comprehensive transparency and the ability to quickly track information about the origin of products, their characteristics, environmental footprint and compliance with sustainable development standards.

However, currently, in the Ukrainian metallurgy and related transport and logistics sectors, there is fragmentation of information systems. The lack of unified integrated digital platforms for all participants in the chain, weak interaction of accounting and logistics systems of enterprises, limited use of modern digital solutions for monitoring the movement of goods, automatic documentary support and data exchange significantly complicate transparency and coordination of processes. This creates room for inconsistencies, delays in delivery, increases the risk of losses and errors and, most critically, hinders compliance with modern EU regulatory requirements.

In particular, the adopted EU Directive on Due Diligence in Sustainable Supply Chains (CDRDD) directly obliges companies operating in the European market to ensure a high level of transparency and control at all stages of supply, including monitoring the social, environmental and ethical aspects of production and transportation of products. One of the key tools for implementing these requirements is Product Digital Passports (PDP), which must contain complete, reliable and up-to-date information on the origin of raw materials, production conditions, carbon footprint and environmental responsibility.

Without proper digitalization of logistics and supply chain management, the accumulation and prompt updating of such information is impossible. The lack of a transparent digital infrastructure deprives Ukrainian manufacturers of the opportunity to effectively prepare and verify digital product passports, which becomes not just a technological gap, but a strategic barrier to access the EU market.

Thus, the digitalization of logistics processes and supply chains, including the creation of unified information platforms, the integration of systems of all chain participants and the active use of cargo monitoring solutions, is critically necessary not only to increase transportation efficiency, but also to meet new EU regulatory requirements, the preparation of digital product passports and the real integration of Ukrainian metallurgy into the steel supply chains of the European market.

Solving these problems requires a comprehensive approach that includes infrastructure development, digital transformation of logistics processes and effective interstate coordination to minimize logistics risks and ensure the reliability and sustainability of supplies of Ukrainian metallurgical products to the EU.

Innovative development of multimodal supply chains is impossible without the implementation of effective transportation control tools, especially in the context of increasing complexity of global supply chains, increasing environmental standards and the need to ensure the safety of cargo. Monitoring delivery, responding promptly to emergencies, preventing illegal interference in the transportation process and minimizing the environmental impact of transportation are critical elements of modern logistics that directly affect the reliability and sustainability of supply chains.

In this context, unmanned civil aircraft systems (UAS) demonstrate significant potential for solving these tasks. Due to their mobility, high efficiency and the ability to monitor in hard-to-reach areas, UAS provide constant control over the movement of cargo, allow for timely detection of violations or threats, as well as environmental monitoring, for example, recording leaks of harmful substances or contamination of territories in the event of transport incidents.

The effectiveness of using UAS in logistics and environmental monitoring is confirmed by many years of scientific research carried out by leading domestic and international institutions. In particular, scientists from the State University "Kyiv Aviation Institute" (Kyiv, Ukraine), the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (Kyiv, Ukraine) and the Institute of Aviation (ILot) (Warsaw, Poland) focus their research on issues of technical improvement, safety of use and expansion of functional capabilities of unmanned aircraft systems for the needs of transport logistics. The results of these studies create a scientific basis for the widespread introduction of UAS into the system of multimodal transportation and sustainable supply chains [27].

The environmental aspect of sustainable supply chains. Transportation of metallurgical products, in particular by rail, plays a key role in the formation of sustainable supply chains between Ukraine and the EU countries. At the same time, this type of transportation is often accompanied by environmental risks, especially in cases of transportation of specific cargoes of the metallurgical complex, such as pig iron, ferroalloys, metallurgical coke, metallurgical waste or associated hazardous chemicals used in production or transported together with metal products.

Railway transport, which is one of the basic sectors of the Ukrainian economy, provides transportation of a significant volume of cargo of various properties, which, if safety measures and precautions are not observed during their transportation, can pose a threat to transport workers, the population, and the environment. Early response to the threat of an emergency, including an ecological one, is carried out on the basis of monitoring data, environment assessment, research and forecasts regarding the possible course of events in order to prevent the further development of such a situation or mitigate its possible consequences.

Based on the analysis of the current state of transportation of dangerous goods by rail in Ukraine, it is shown that the characteristic consequences of emergency situations during the transportation of such goods are leakage (80.7%), spontaneous combustion (11.2%) and evaporation (5.6%), which necessitates the creation of a set of organizational and technical measures aimed at carrying out effective actions to reduce the harmful impact on the environment and human life of the negative factors of these situations [28]. It was revealed that there is an antagonistic contradiction between the parties to a railway emergency situation (natural and man-made factors and targeted actions of liquidation units), a feature of which is the presence of an ecological hazard of the "stay" of natural mechanisms at the place of resolving the contradiction, while the concentration of liquidation units and the organization of their actions by the operational headquarters still requires certain efforts and time.

Studies of environmentally hazardous transport events in the railway sector [29] show that such situations have a complex, sometimes latent nature of development, the final consequences of which can be explosions, fires, destruction of rolling stock and infrastructure, loss of life and large-scale environmental pollution. In particular, three typical scenarios of the development of events are:

- Slow accumulation of negative factors (for example, technical wear of wagons, violation of loading or fastening rules of metal products), which does not reach critical limits, but creates a constant hidden source of risk.
- Accumulation of negative factors with a gradual exit beyond critical limits, which can

lead to serious incidents, in particular when transporting metal products as part of mixed cargo together with flammable or chemically hazardous substances.

• Rapid accumulation of critical factors, for example, due to an emergency situation, poor-quality maintenance of rolling stock or external influence (sabotage, shelling in war conditions), which directly leads to catastrophic consequences.

In view of the above, ensuring effective monitoring of metallurgical product transportation is not only a matter of logistics optimization, but also a critical condition for reducing environmental and man-made risks. The implementation of modern digital solutions, real-time tracking systems, as well as the use of unmanned aircraft systems to monitor the movement and condition of railway cargo will allow for timely detection of dangers, forecast the development of emergency situations and minimize their negative consequences for both the economy and the environment.

In the context of metallurgical product transportation, the application of the theory of queuing systems (QS) methods is a traditional approach to modeling logistics flows, managing the load of transport nodes, as well as assessing delays, queues and the efficiency of resource allocation in transport systems [29, 30]. However, the full-scale aggressive war of Russia against Ukraine in 2022–2025 significantly changed the conditions for the functioning of logistics in the country, which necessitates a rethinking of the tasks that are solved within the framework of this theory. In particular, for the transportation of metallurgical products, which is critically important for both domestic industry and exports to EU countries, a number of new challenges arise:

• limited number of transport corridors due to the destruction of infrastructure or their congestion;

• growing competition between different types of cargo for the use of limited logistics capacities (with some cargoes having priority - for example, humanitarian aid or military support);

• frequent disruptions in schedules due to shelling, energy crises, or sudden changes in logistics due to security threats.

In wartime conditions, classic QS should be supplemented with modeling components with priorities, where certain categories of cargo (in our case, metallurgical products as a strategic export) are given an increased level of access to limited resources - ports, border crossings, freight cars, warehouses, etc. Taking into account priorities allows us to assess the impact of decisions on dispatching, rerouting or redistributing cargo flows on the overall efficiency of supply chains and their environmental footprint.

In addition, QS with priorities can be used for environmental and economic assessment: for example, to determine which logistics service scenarios (via which transport corridor, with what delays, at what load levels) lead to a smaller carbon footprint or reduced pollution risks. This is especially relevant in the context of increased environmental requirements for metal products in the EU (in particular through CBAM and CDRDD), where not only production, but also transportation is taken into account when assessing the overall sustainability of products.

In the current conditions of transportation of metallurgical products from Ukraine, especially in conditions of war and partial destruction of transport infrastructure, the problem of effective distribution of limited logistical resources has acquired critical importance. In particular, we are talking about a limited number of locomotives, wagons, port capacities and the throughput capacity of railway corridors that remain functional. In such conditions, prioritization of cargo is not only an organizational, but also an economic and strategic necessity. According to the logic, which is confirmed by the theory of priority-based queuing systems, the first right to transportation is given to cargoes that are critical for national security, defense or emergency response.

At the same time, other cargoes, including metallurgical products, which are the basis of Ukraine's export potential and one of the key areas of post-war economic reconstruction, also require a clear prioritization system. In this context, it is advisable to apply the criterion of the ratio of the cost of the cargo (economic value for the state or enterprise) to the time remaining before the deadline for delivery to the destination station or to the customer. This approach allows for the most efficient use of limited transport resources, minimize economic losses and avoid disruptions in strategically important supply chains.

This is especially true for metallurgical products that have high added value, are export-oriented and directly affect the state's foreign exchange earnings and the fulfillment of contractual obligations to European partners. Delays in their delivery can not only lead to fines and reputational losses, but also jeopardize the integration of Ukrainian metallurgy into the EU's steel supply chains.

The application of the mathematical apparatus of priority-based QS optimization allows to automate and justify these decisions. Such models take into account the real state of the infrastructure, the number of available locomotives, the downtime of cargo, the economic significance of products and time constraints, which makes transport planning as efficient and transparent as possible.

The complexity of implementing analytical methods of the theory of QS is determined by the volumetric forms of the mathematical description of their functioning. Therefore, when solving the scientific problem, it is advisable to use computer simulation methods. In the monograph [28], a partially modified QS was studied using the MathLab Simulinc simulation model development environment (with the SimEvent and StateFlaw libraries, see Pic.1). It is shown that with the help of dynamic priorities, the priority of a non-priority customer is increased once, while the probability of serving these customers increases. However, such a characteristic of QS as the probability of serving the flow of arriving consumers decreases, since non-priority consumers are served longer than priority consumers.

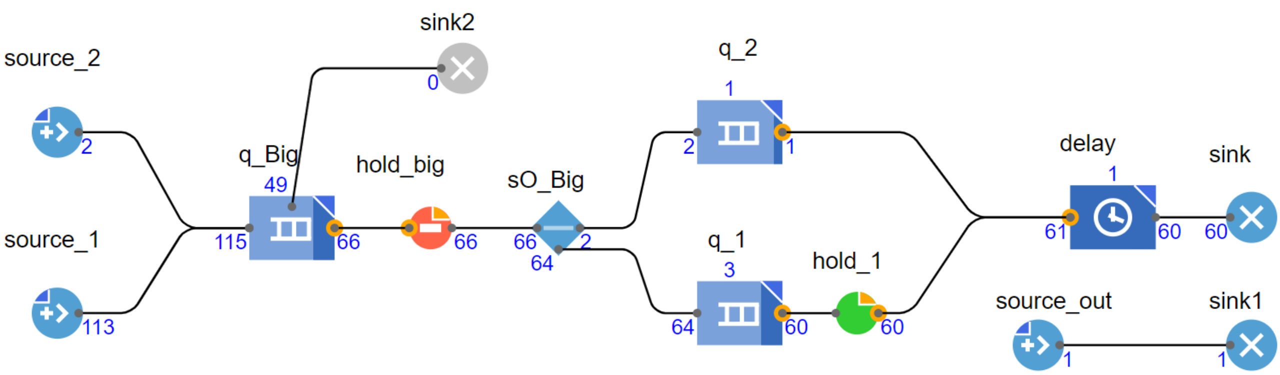

Figure 1 – The main window of the simulation model in the AnyLogic environment
Source: developed by M.Katsman

Taking into account the practical experience of functioning and ensuring the reliability of the railway transport system in extreme conditions of military operations, destruction and restoration of infrastructure, shortage of time and fleet of vehicles, it is proposed to formalize the functioning of this system as a queuing system with priorities, with variable parameters of arrival and servicing the consumers of higher and lower priorities, which allows making more informed decisions for the management of such systems.

The necessity of using, along with analytical methods, simulation modeling tools has been proven, in particular, a simulation model has been developed and implemented, which combines agent and discrete-event simulation principles and allows studying QSs when consumers of different priority are arriving, namely in the part of establishing regularities: probabilities (service, refusal, push-out), time delays (waiting in a queue, under service), queue sizes, order of queue formation when customers of different priority arrive.

The resulting dependencies:

- the probability of servicing higher priority consumers depending on arrival and servicing rates;

- probabilities of servicing lower priority consumers depending on arrival and servicing rates of higher priority consumers;

- probability of "pushing" lower priority consumers out the QS by higher priority consumers, depending on arrival and service intensities of higher priority consumers;

- values of the intensity of service of higher priority consumers μH on the probability PH and the intensity of their arrival λH ;

- values of the probability of PL on the values of the intensity of service μH of the consumers of the highest priority and the duration of the interval tH between these consumers in the arrival flow.

The proposed approach to the study of the consequences of hazardous rail traffic accidents with dangerous goods:

- is the methodological basis for the creation and development of Decision Support System for Task Force leader in the aftermath of such accidents in a single automated control system of railway freight transportation;

- makes it possible to formulate reasonable requirements for the deployment of wreck, recovery and fire teams on the rail network, their equipment and the professional training for team leaders, managers and staff;

- enables to determine the probability and duration of the negative impact of environmentally hazardous transport accidents.

The new multi- and inter- modal transportation planning and management requirements should support innovation in transportation system, its components, their operation and maintenance. They must allow for the smooth integration of new technologies into the system operation domain. Also, the development of new production standards and safety and certification rules by regulators often lag behind technological development, bringing product development to a halt, including new equipment and technologies. Therefore, it is appropriate to include in the service system the possibility of the occurrence of force majeure circumstances and to consider the system with their impact on the results. The proposed theoretical approach consists in the fact that in a multi-component queueing system, the value of the probability of serving a customer in a certain QS component can be determined taking into account that the second component contains the sum of all probabilities of the "enlarged" states of other components of the QS.

Based on this theoretical provision, the modelling of transport maintenance and repair processes, using the example of the repair enterprise, allows to determine the necessary initial parameters of the system components as interacting QSs and to obtain the largest values of the probabilities of servicing the arriving customers in these components and the system as a whole, which provide an acceptable level of its reliability.

When studying real production, logistics, and other systems for which the mathematical apparatus of queueing theory is adequate, the necessary initial mathematical parameters of the system components must be expressed through physical parameters (flows of vehicles or other objects requiring maintenance, performance of equipment for various types of work, production tasks, time constraints, etc.), which will make it possible to optimize specific technologies and enterprises.

When modelling QS processes, non-standard system dynamics solutions were proposed in the AnyLogic University Researcher environment, which allowed to:

- solve a multi-rank system of Kolmogorov equations;
- implement multi-iterative sensitivity experiments with the initial parameters of the QS;
- obtain experimental dependences of the influence of all key parameters on QS indicators, in particular, service probabilities.

The described mathematical apparatus and modelling tools have shown their relevance to real processes and can be applied to improve the performance of multi-component and multiphase queueing systems, which reflect the technological processes occurring in real production, transport-logistics and other systems intended for operation, maintenance and repair of technical equipment of various nature.

The QS model was implemented using System Dynamics computer simulation in the AnyLogic University Researcher environment [29]. The proposed approach to the modelling of maintenance and repair processes in transportation sector by production divisions of the enterprise as a multi-component and multi-phase QS allows to determine the effectiveness of the functioning of such a QS and to obtain arguments for increasing the efficiency of its operation. The graph of the QS states is presented in Fig 2. In Fig. 2 it is indicated:

$\mu_{11} = \mu^{/} + \beta_1^{/}$; $\mu_{12} = 2\mu^{/} + 2\beta_1^{/}$; $\mu_{13} = \mu_{12} + \gamma_1^{/}$; $\mu_{14} = \mu_{12} + 2\gamma_1^{/}$; $\mu_{15} = \mu_{12} + 3\gamma_1^{/}$; $\mu^{/} = 4\mu_1$; $\mu_1 = \frac{1}{\bar{t}_{s_1}}$; $\beta_1^{/} = 4\beta_1$; $\beta_1 = \frac{1}{\bar{t}_{lims_1}}$; $\gamma_1^{/} = 4\gamma_1$; $\gamma_1 = \frac{1}{\bar{t}_{limw_1}}$; $\mu_{21} = \mu^{//} + \beta_2^{//}$; $\mu^{//} = 3\mu_2$; $\mu_2 = \frac{1}{\bar{t}_{s_2}}$; $\beta_2^{//} = 3\beta_2$; $\beta_2 = \frac{1}{\bar{t}_{lims_2}}$; $\mu_{22} = \mu_{21} + \gamma_2^{//}$; $\gamma_2^{//} = 4\gamma_2$; $\gamma_2 = \frac{1}{\bar{t}_{limw_2}}$; where $\bar{t}_{lims_1}$, $\bar{t}_{lims_2}$ are the limited service time; $\bar{t}_{lim...}$, $\bar{t}_{lim...}$ are the limited waiting time.

The above-mentioned initial parameters reflect and quantitatively characterize both the external conditions of the system's functioning (λ) and its internal capabilities and limitations (μ, β, γ) in response to changes in external conditions, including force majeure circumstances. The simulation model of this two-component QS is presented in Fig. 3. The generalized characteristics of the QS of the system components are the service probabilities Ps/ and Ps//. These characteristics include the initial parameters and some other parameters of the QS components. In the calculation example, the boundary value of the service probabilities of QS components Pb.vs = 0.6 is set, i.e. Ps/ and Ps//must not be less than 0.6 at the same time, provided that the components serve requirements with the same priorities. The results of experiments on the sensitivity of the model are presented in Fig. 4. It can be seen that the determined results of the initial parameters, which correspond to the boundary condition, make it possible to obtain the most acceptable values of the probability values Ps/, Ps//and Ps [29].

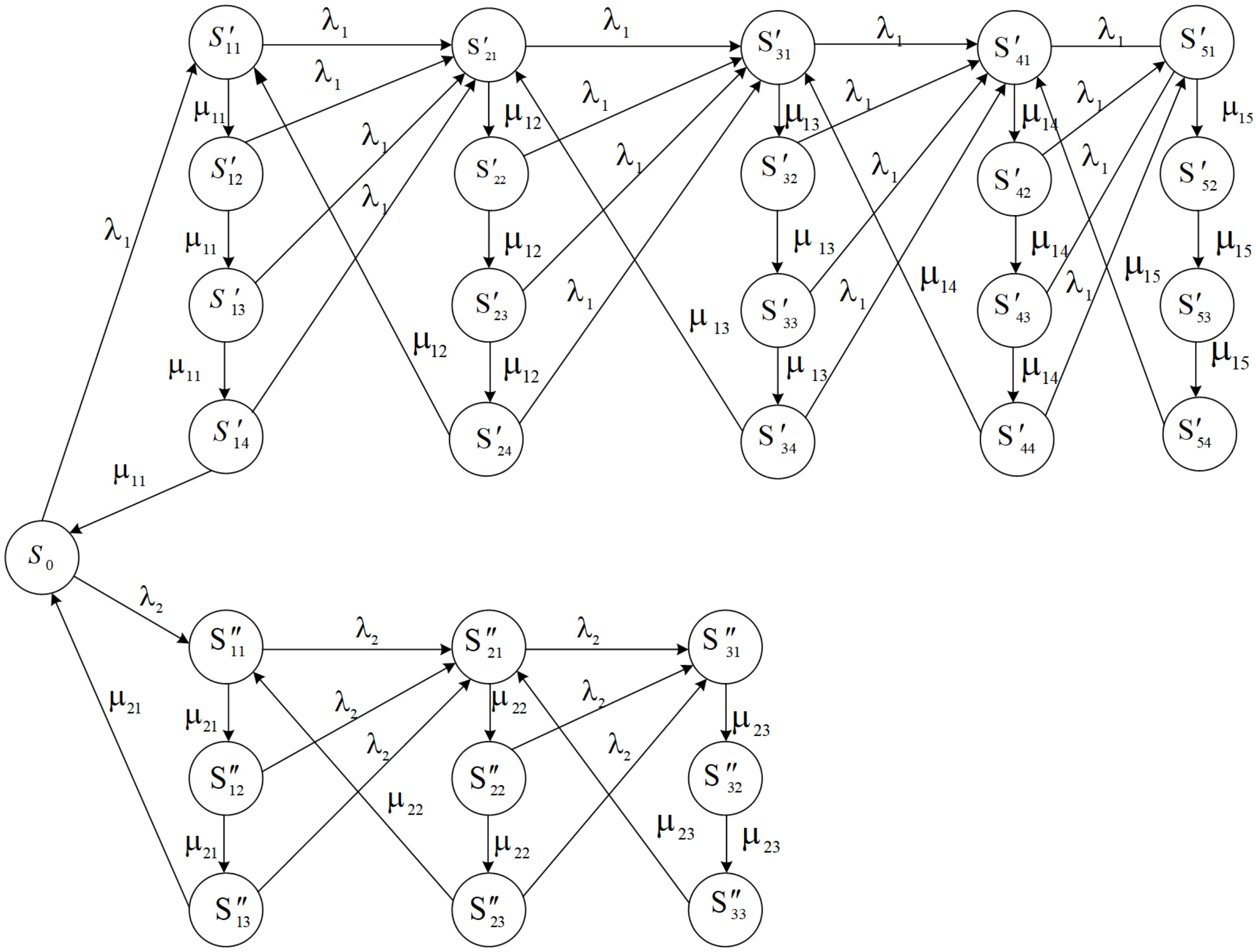

Figure 2 – State graph of QS with restrictions on the time spent in the service period β1,2 and waiting γ1,2

Source: developed by O. Zaporozhets & M.Katsman

New hazards concerning the transportation operation and maintenance of the new equipment and systems should be investigated to complete the safety analysis of new Green Deal Directive outcomes increasing their sustainability in the future. However, the proposed mathematical apparatus must cover new links and allow safe and sustainable solutions.

Strategic safety management of transport systems in the post war period is an effective tool in the process of ensuring sustainable development of the national economy of Ukraine as a whole and the industry in particular [30].

Prospects and ways of integrating Ukrainian metallurgy into the EU steel supply chain. Despite the devastating consequences of the war, the loss of part of its industrial capacity, disruption of logistics and the intensification of competitive pressure on global markets, Ukraine still retains the strategic potential to restore and modernize its metallurgical complex. Moreover, the current situation creates a unique combination of internal and external factors that can not only return the industry to its pre-war level, but also ensure its sustainable competitiveness in accordance with the modern requirements of the green economy.

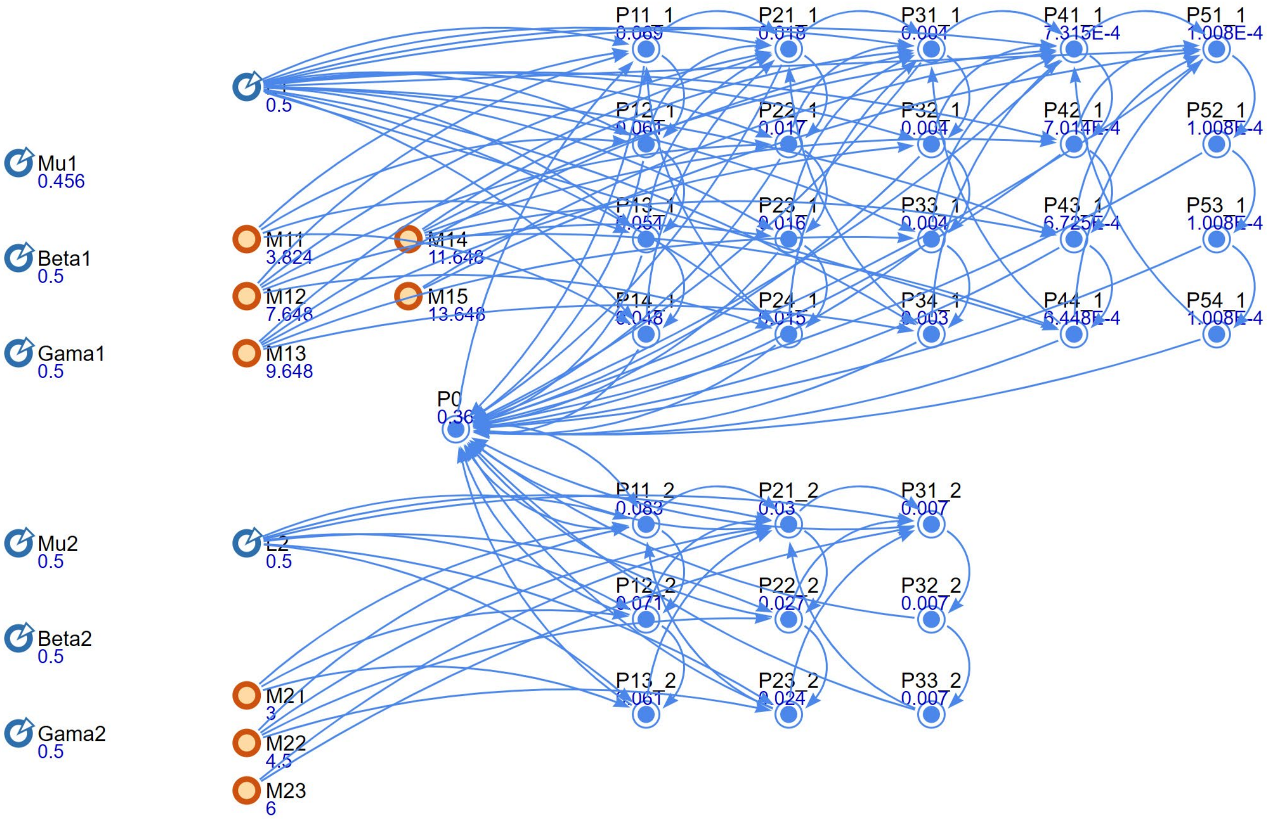

Figure 3 – Probability density of grain delivery time distribution at optimal sizes of the fleet of vehicles (trucks, ships, etc)

Source: developed by O. Zaporozhets & M.Katsman

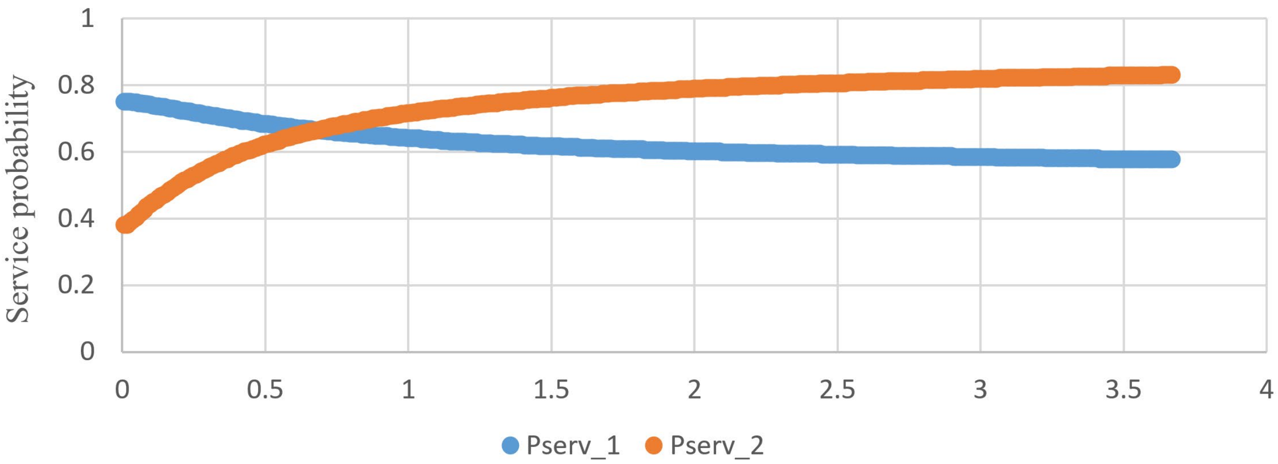

Figure 4. – Graph of the dependence of the probabilities Ps/ and Ps//on the parameter μ/

Source: developed by O. Zaporozhets & M.Katsman

First of all, Ukraine has a powerful resource base - iron ore reserves, which remain one of the largest in Europe. Ukraine has one of the largest reserves of magnetite ores in the world (5 billion tons), suitable for enrichment to an iron content of 68-70%. These products will be in demand in the future as the main raw material for the production of low-carbon steel in electric arc furnaces using DRI. Ukraine will help the global metallurgical industry in its green transition, having the potential to supply 20-25 million tons of DR-quality iron ore raw materials and, thus, satisfying a significant part of the market demand. This is a fundamental factor for the formation of competitive export-oriented metallurgical production. In addition, the country has significant potential for the development of renewable energy, in particular "green" electricity and the hydrogen economy, which are key prerequisites for the creation of low-carbon metallurgical production.

The post-war reconstruction of Ukrainian industry opens a unique "window of opportunity" for the construction of new metallurgical capacities on the principles of climate neutrality, which is due to a complex of economic, technological, political and natural resource factors.

Firstly, a significant part of Ukraine's metallurgical infrastructure has been physically destroyed as a result of military operations, and therefore, the country finds itself faced with the need not to modernize outdated plants, but to actually build new production facilities "from scratch". This significantly simplifies the integration of modern low-carbon technologies, since new construction is technologically and economically more profitable for the implementation of "green" metallurgy standards than the re-equipment of outdated Soviet-style enterprises. This is what is currently being actively implemented by leading countries in the world, in particular Sweden and Germany, building new steelworks based on the principle of using "green" hydrogen and electricity from renewable sources.

Secondly, Ukraine has competitive natural prerequisites for the implementation of low-carbon metallurgical production. In particular, this is access to significant deposits of iron ore, the potential for the production of "green" hydrogen due to the presence of a developed renewable energy sector (wind and solar), as well as geographical proximity to European steel consumption markets. According to European think tanks, Ukraine can play a key role as a supplier of climate-neutral raw materials and products to support the EU's "green" transition within the framework of the European Green Deal.

Third, the post-war recovery is being revived against the backdrop of increased regulatory requirements of the European Union, in particular regarding the carbon footprint of products (CBAM) and the sustainability of supply chains (CDRDD). Therefore, the focus on climate-neutral metallurgy not only corresponds to global environmental trends, but is also a necessary condition for maintaining access of Ukrainian products to the European market.

In addition, the availability of international financial and technological support, including through military reconstruction mechanisms, investment programs and international climate funds, creates a favorable environment for the implementation of such large-scale projects.

Ukrainian metallurgical companies are already planning for this green future. For example, Metinvest is going to build two DRI modules in Ukraine, with an annual capacity of 2.5 million tons each. They supply DRI to the new electric arc complexes of the Zaporizhstal and Kametstal plants. In 2024, Metinvest Group, under difficult war conditions, increased environmental spending and increased its focus on energy efficiency. According to a new report, the company allocated $170 million to environmental protection, which is 2% more than in 2023. Investments in energy efficiency facilities also increased - by more than 50% y/y, to about $17 million. The company continues to develop energy autonomy, in particular, through the installation of gas piston units and plans to launch solar power plants. In 2025, Metinvest began the active phase of the project to thicken enrichment waste at the Severny GOK, which will reduce the load on the tailings. By the end of 2024, 15 Metinvest assets were certified according to the environmental standard ISO 14001:2015, and seven - according to the energy management standard ISO 50001:2011. Thus, the company demonstrates a systematic approach to environmental management and a gradual transition to sustainable production even in wartime conditions. Metinvest is actively preparing for new conditions and transforming its business according to ESG (Environmental, Social, Governance) principles. The EU is introducing new non-financial reporting standards that are radically changing business requirements. Currently, high-quality products are not enough to operate on the European market - they must report on environmental impact, social responsibility and corporate governance.

Ukrainian metallurgical companies are already actively preparing for a green future, focusing on market requirements and global trends in sustainable development. Also, Metinvest Group demonstrates a systematic approach to business transformation in accordance with low-carbon production standards and ESG (Environmental, Social, Governance) principles. The company plans to build two modern direct iron reduction (DRI) modules in Ukraine with an annual capacity of 2.5 million tons each. The DRI products will be produced at new electric arc steelmaking complexes at Zaporizhstal and Kametstal, which will significantly reduce the carbon footprint of steel production.

In the context of war, in 2024 Metinvest continued to increase environmental investments, directing $170 million to environmental protection - this is 2% more than in 2023. Investments in energy efficiency facilities increased significantly, by more than 50% in annual terms, reaching almost $17 million. Among the company's key initiatives is increasing the energy autonomy of enterprises through the installation of gas-piston power plants and the implementation of solar energy projects.

Also in 2025, Metinvest moved into the active phase of implementing the enrichment waste thickening project at the Northern Mining and Processing Complex (GZK), which allows reducing the load on the tailings and improving the environmental performance of the enterprise. At the end of 2024, 15 asset groups were already certified according to the international environmental standard ISO 14001:2015, and seven enterprises - according to the energy management standard ISO 50001:2011, which confirms the systematic approach to environmental management and sustainable production even in wartime.

This approach is quite justified, given the new rules of the game on the European market. In particular, the EU is gradually introducing new standards for non-financial reporting and business sustainability regulation, which radically changes the requirements for suppliers. From now on, to enter the European market, it is not enough to have only high-quality products - companies must transparently report on the environmental and social impact of their activities, adhere to corporate governance standards and meet sustainable development criteria. Therefore, Metinvest's steps to prepare for the new conditions of international trade are not only a forced adaptation to the regulatory environment, but also a strategic investment in the competitiveness of Ukrainian metallurgy in the conditions of post-war reconstruction and transition to a green economy.

ArcelorMittal is also considering the possibility of switching from traditional blast furnace production to electric steelmaking technologies using DRI, as practiced in its European divisions. In particular, outdated coke ovens and a sinter plant were decommissioned in 2022–2023, which allowed to reduce emissions by more than 60,000 tons of CO2 per year.

Mining and processing company Ferrexpo has set a goal of achieving zero CO2 emissions (Scope 1+2) by 2050 and investing $3.3 billion in modernization. In 2023, Ferrexpo reduced the carbon intensity of the pellet production process (Scope 1 + 2) by 32% compared to the 2019 baseline. By 2030, the company intends to reduce the carbon intensity of production by 50%. Among the leading projects that will provide the bulk of the carbon reductions, Ferrexpo identified the following: transition to biofuels in the pelletizing process; gradual abandonment of fossil fuels; electrification of technological mining vehicles and equipment; use of hydrogen-powered barges. According to the company's calculations, these measures should provide 90% of the potential emission reduction and are the basis of its Net Zero strategy. At the same time, the first three measures play a leading role - they account for 82% of the emission reduction [32].

Ferrexpo and Metinvest have already established the production of DR pellets, and ArcelorMittal Kryvyi Rih was preparing a pellet plant with a capacity of 5 million tons per year (the project was suspended due to the war, but with high potential for recovery). The Canadian company Black Iron planned to produce high-quality concentrate (4–8 million tons per year), the project was suspended, but has great prospects after the war gmk.center. According to GMK Center, Ukraine can become a key player in the European DRI/HBI market, with a potential of 20–25 million tons, which corresponds to approximately 14% of global demand.

Thus, Ukrainian metallurgical giants - Metinvest, ArcelorMittal Kryvyi Rih, Ferrexpo, Interpipe - are already implementing, albeit different, but complementary initiatives to transition to low-carbon technologies. This includes DRI modules, electric steelmaking, fuel decarbonization, construction of pellet plants and hydrogen projects. These steps demonstrate a systematic approach to a true green transformation of the national metallurgy and create a foundation for integration into the EU's "green" supply chains.

According to GMK center estimates, the total capital expenditures required to implement the already announced "green" metallurgy projects in Ukraine are about $11 billion. These projects will be implemented only on condition that Ukrainian companies receive access to European "green" financing instruments, similar to those received by European companies. Thanks to this support Ukrainian metallurgy can become an important part of the European low-carbon supply chain, which will be beneficial for all stakeholders, and especially for European metallurgy.

Conclusions. The analysis of current trends and strategic factors in the development of sustainable supply chains of metallurgical products from Ukraine to the European Union allows us to draw a number of important conclusions. First, Ukraine's unique geographical location creates competitive advantages for integration into European supply chains. Proximity to key EU markets, convenient access to Black Sea ports, and active participation in projects to develop transport and logistics infrastructure contribute to reducing transportation costs and the carbon footprint of supplies. This, in turn, increases the attractiveness of Ukrainian metallurgical products for European partners, who are increasingly focused on environmental performance and supply chain efficiency. Second, the political factor plays a key role in creating a favorable environment for the development of sustainable supply chains. The status of a candidate country for accession to the EU opens up for Ukraine the possibility of deeper economic integration, which includes the harmonization of environmental and social standards, access to financing within the framework of European reconstruction programs, as well as the attraction of modern technologies and investments for the modernization of the industry. This creates a foundation for increasing the competitiveness of the Ukrainian metallurgy in the European market.Thirdly, the strategic transition of the EU economy on the basis of the European Green Deal forms a long-term and stable demand for climate-neutral raw materials and products. In particular, the demand for steel with a low carbon footprint, the production of which is possible due to the use of DRI technologies, green hydrogen and renewable energy, opens up a unique "window of opportunity" for Ukraine. Under the conditions of proper modernization of production facilities, development of logistics infrastructure and compliance with modern environmental standards, Ukraine is able to become an important element of European green supply chains. Thus, a complex combination of geographical, political and economic factors, as well as the desire to restore and decarbonize the national metallurgy, creates the prerequisites for the active integration of Ukraine into sustainable EU supply chains, which, in turn, will contribute not only to the development of Ukrainian metallurgy, but also to the overall post-war economic reconstruction of the country. The development of sustainable supply chains of metallurgical products from Ukraine to the European Union is not only a strategic condition for economic integration, but also a key factor in increasing the competitiveness of Ukrainian metallurgy in the post-war period. At the same time, it is the logistics component that plays a decisive role in the formation of effective and sustainable supply channels that can meet the modern requirements of the EU market and regulatory environment. Today, the Ukrainian metallurgical industry faces significant logistical challenges: a limited number of transport corridors, overloaded border crossings, high transportation costs, difficult coordination between different modes of transport, and insufficient digitalization of logistics processes. These factors not only reduce the reliability and predictability of supplies, but also increase the carbon footprint of products due to inefficient use of transport infrastructure. At the same time, the development of sustainable logistics solutions - diversification of transport routes, modernization of railway and port infrastructure, transition to multimodal environmentally friendly transportation, digitalization of supply chains - is a necessary condition for the integration of Ukraine into the green supply chains of the EU. It is the optimization of logistics that will allow to reduce the time and costs of transportation, reduce greenhouse gas emissions at the delivery stage and increase the overall transparency and compliance of supplies with modern environmental standards, which is becoming increasingly relevant in the context of the implementation of such European initiatives as the Green Deal, CBAM and CDRDD. These factors create a unique "window of opportunity" for the integration of Ukrainian metallurgy into the green supply chains of the European Union. The essence of these chains is not only to reduce the carbon footprint of finished products, but also to comply with high standards of transparency, social responsibility and environmental safety at all stages - from raw material extraction to delivery to the end consumer. The results of the study show that the digitalization of metallurgical supply chains is a critical prerequisite for Ukraine's integration into sustainable EU supply chains. In the context of new EU regulatory requirements, such as the CDRDD and Ecodesign Regulation, without an adequate level of digital transparency, Ukrainian manufacturers will not be able to ensure the necessary level of traceability, environmental responsibility and the formation of digital product passports. To do this, Ukraine needs to systematically develop unified digital platforms for supply chain participants, integrate information systems in accordance with European standards, invest in digital infrastructure and stimulate business to implement modern IT solutions. Without such measures, the creation of sustainable, transparent and competitive supply chains of metallurgical products from Ukraine to the EU will remain a difficult task, which will hinder the country's post-war economic reconstruction and integration into the European market.In Ukraine, environmental protection is being done in accordance with state requirements at the moment. Its improvement is possible due to step-by-step implementation of the European rules and principles including the Green Deal portfolio. Thus, with the right policy, state support, and cooperation with European partners, Ukraine has a real chance to make a strategic "leap" into the future, transforming the metallurgical industry from a post-conflict vulnerable sector into one of the drivers of economic recovery and an important component of Europe's green transformation.

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Mukha T.A Postgraduate student, Kharkiv national automobile and highway university, Kharkiv, (Ukraine)

ORCID – 0009-0008-9282-6833
Researcher ID – JFA-1459-2023
Scopus author id: – 59539916400
E-Mail: hammers.plant@gmail.com

PROCESS MINING-DRIVEN DIGITAL TRANSFORMATION OF ENTERPRISE LOGISTICS FOR CIRCULAR AND SUSTAINABLE SUPPLY-CHAIN PERFORMANCE

Taras Mukha. "Process mining-driven digital transformation of enterprise logistics for circular and sustainable supply-chain performance". *This article investigates how process mining catalyzes the digital transformation of enterprise logistics toward circular and sustainable supply-chain performance. Using a systematic analysis of academic research from 2019–2025, triangulated with industry implementations and technology assessments, the study explains how process mining reshapes logistics decision-making across discovery, conformance, enhancement, prediction, and operational support. Findings show organizations implementing process mining achieve 20–40% operational cost reductions while advancing environmental objectives. Convergence with Industry 4.0—artificial intelligence, IoT, blockchain, and digital twins—creates end-to-end visibility and optimization across multi-tier networks. Object-centric process mining, commercialized in 2022, overcomes classical limitations by jointly analyzing orders, shipments, and invoices, exposing many-to-many relations typical of logistics flows. The research extends the Resource-Based View by positioning process-mining capabilities as VRIN assets and applies Dynamic Capabilities to explain sensing, seizing, and transforming behaviors enabled by real-time process intelligence. An integrated framework combines process mining with circular-economy principles and sustainability metrics; evidence indicates a positive correlation (r=0.34) between process-mining adoption and sustainable supply-chain performance. A five-level maturity model structures the pathway from reactive operations to autonomous, AI-driven supply chains. Implementation analysis highlights the centrality of enterprise integration and identifies data-quality remediation—about 80% of effort—together with organizational resistance and skills gaps as critical challenges. Enterprise contexts emphasize SAP integration for real-time analysis, reinforcing the need for strong data governance and cloud-native scalability. Cross-industry cases report 25–50% cycle-time reductions, 40–60% error decreases, and 15–30% environmental-impact reductions. The framework operationalizes value measurement through balanced KPIs spanning process efficiency, utilization, conformance, emissions accounting, material circularity, and financial outcomes, while a staged roadmap details assessment, foundation, pilot, scale, and continuous optimization phases. Future research should examine the interplay of process mining with quantum optimization, generative AI, 5G and edge computing, digital twins, hyperautomation, and blockchain as these capabilities enable real-time, trusted, and prescriptive analytics at scale. Overall, the study shows that process mining provides the visibility to diagnose actual operations and the* *intelligence to optimize for multiple objectives, equipping enterprises with the structures, metrics, and governance needed to progress toward circular and sustainable supply-chain performance.*

***Keywords**:* process mining; digital transformation; sustainable supply chain; circular economy; enterprise logistics; Industry 4.0; sustainability metrics; ERP integration; object-centric process mining; material circularity indicator; triple bottom line; dynamic capabilities

Тарас Муха. «Цифрова трансформація логістики підприємства на основі Process Mining для забезпечення циркулярності та сталості функціонування ланцюгів постачання». *Стаття досліджує, як процесний майнінг каталізує цифрову трансформацію логістики підприємств у напрямі циркулярної та сталої продуктивності ланцюгів постачання. Методологію становить систематичний аналіз праць 2019–2025 рр., зіставлений із задокументованими впровадженнями та оцінкою зрілості технологій. Показано, що впровадження процесного майнінгу забезпечує 20–40% зниження операційних витрат при одночасному досягненні екологічних цілей. Синергія з Індустрією 4.0—штучним інтелектом, IoT, блокчейном і цифровими двійниками—формує наскрізну видимість та новий рівень оптимізації багаторівневих мереж. Об'єктно-орієнтований підхід, комерціалізований у 2022 р., долає обмеження класичних методів завдяки спільному аналізу замовлень, відвантажень і рахунків. Теоретично робота розширює ресурсний підхід і динамічні спроможності, трактуючи компетенції процесного майнінгу як стратегічні активи, що підсилюють здатність відчувати, схоплювати та трансформувати можливості в реальному часі. Синтез результатів приводить до інтегрованої рамки, що поєднує процесний майнінг із принципами циркулярної економіки та метриками сталості; зафіксовано позитивну кореляцію (r=0.34) між рівнем впровадження та сталою ефективністю ланцюга постачання. Запропонована п'ятирівнева модель зрілості структурує шлях від реактивних операцій до автономних, керованих ШІ ланцюгів. Ключові виклики: інтеграція з корпоративними системами (зокрема SAP), домінування робіт із забезпечення якості даних (≈80% зусиль), організаційний опір і дефіцит навичок. Кейси показують 25–50% скорочення циклового часу, 40–60% зниження помилок і 15–30% зменшення екологічного впливу. Рамка операціоналізує створення цінності через збалансовані KPI та поетапну дорожню карту: оцінювання, базова підготовка, пілот, масштабування, безперервна оптимізація. Перспективи досліджень пов'язані з інтеграцією процесного майнінгу з квантовою оптимізацією, генеративним ШІ, 5G/edge-обчисленнями, цифровими двійниками та гіперавтоматизацією. У підсумку процесний майнінг забезпечує видимість фактичних операцій і інтелект для багатоцільової оптимізації, створюючи підґрунтя керованого руху до циркулярних і сталих ланцюгів постачання.*

Ключові слова: процесний майнінг; цифрова трансформація; сталий ланцюг постачання; циркулярна економіка; логістика підприємств; Індустрія 4.0; метрики сталості; інтеграція ERP; об'єктно-орієнтований процесний майнінг; індикатор циркулярності матеріалів; потрійний критерій; динамічні можливості

Introduction. The global logistics industry faces unprecedented pressure to simultaneously enhance operational efficiency and environmental sustainability. With supply chains accounting for more than 80% of consumer companies' greenhouse gas emissions and 90% of their environmental impact [1], the imperative for transformative change has never been more critical. This research investigates how process mining technologies serve as catalysts for digital transformation in enterprise logistics, enabling the transition toward circular and sustainable supply chain models. Process mining, defined as the extraction of knowledge from event logs recorded by information systems, has evolved from an academic discipline to a mature commercial technology with the global market exceeding $1 billion by 2022 and growing at 40-50% annually [2]. This rapid growth reflects organizations' recognition that traditional approaches to supply chain management are insufficient for addressing contemporary challenges including increasing complexity, sustainability mandates, and stakeholder expectations for transparency. The convergence of process mining with emerging technologies creates unprecedented opportunities for supply chain transformation. Digital twins enable virtual modeling of physical supply chains, achieving 99.9% on-time delivery rates and 30% inventory reduction [3]. Artificial intelligence integration enables predictive analytics with over 90% accuracy in demand forecasting, while blockchain provides immutable tracking of sustainability credentials across multi-tier supply networks [4]. These technological synergies fundamentally reshape how organizations conceptualize, manage, and optimize their logistics operations.

Analysis of Recent Research and Publications. The theoretical underpinnings of process mining-driven digital transformation draw from multiple management theories. The Resource-Based View (RBV) positions process mining capabilities as VRIN resources (Valuable, Rare, Inimitable, Non-substitutable) that enable sustainable competitive advantage [5]. Organizations developing sophisticated process mining competencies create unique insights into their operations that competitors cannot easily replicate, particularly when integrated with proprietary data and organizational knowledge. Dynamic Capabilities Theory extends RBV by explaining how organizations leverage process mining for continuous adaptation [6]. Research demonstrates that process mining enhances three core dynamic capabilities: sensing (real-time visibility into supply chain processes), seizing (rapid optimization of resource allocation), and transforming (continuous reconfiguration for enhanced sustainability) [7]. Academic literature reveals exponential growth in process mining research, with a 340% increase in publications combining process mining and sustainability topics between 2019-2025 [8]. Systematic reviews identify seven key process mining techniques relevant to supply chain management as shown in Table 1.

Table 1 – Process Mining Techniques and Their Supply Chain Applications

Technique	Description	Supply Chain Application	Impact
Process Discovery	Automatic extraction of process models from event logs	Material flow mapping, order processing analysis	95% accuracy in process identification
Conformance Checking	Comparison of actual vs. planned processes	Compliance monitoring, quality assurance	40-60% reduction in violations
Process Enhancement	Optimization of existing processes	Bottleneck elimination, resource allocation	25% efficiency improvement
Predictive Monitoring	Forecasting process outcomes	Delay prevention, disruption management	90% prediction accuracy
Operational Support	Real-time process guidance	Decision support, automated alerts	30% faster response times
Process Comparison	Benchmarking across processes	Best practice identification	20% performance improvement
Variant Analysis	Identification of process variations	Exception handling, customization	35% reduction in variations

Source: Compiled by author based on [8], [9], [10] Seen through a management lens, the techniques constitute a coherent operating system for decisions. Discovery establishes an auditable baseline of how work actually flows; conformance converts that map into enforceable policy by surfacing rule breaks; enhancement redirects scarce capacity from bottlenecks to value; predictive monitoring rebalances supervisory time toward early-warning control; operational support compresses escalation cycles; comparison and variant analysis institutionalize learning across sites and customers. As effects accumulate—higher identification accuracy, fewer deviations, quicker responses, tighter variance—leaders can move from ad-hoc fixes to portfolio-style optimization, aligning incentives, budgets, and accountability with measured behaviour rather than assumptions. Thus process mining becomes a compounding management capability, not a one-off tool, and merits governance and cadence comparable to core performance systems. The evolution from traditional process mining to object-centric process mining (OCPM) represents a paradigm shift. OCPM, introduced commercially by Celonis in 2022, enables simultaneous analysis of multiple interconnected objects (orders, shipments, invoices) across complex supply chains [11]. This advancement addresses fundamental limitations of classical process mining, which struggled with many-to-many relationships common in logistics operations.

The Purpose and Objectives of the Study. This research aims to develop a comprehensive framework for leveraging process mining technologies to drive digital transformation in enterprise logistics, enabling circular and sustainable supply chain performance. Specific objectives include: Analyzing the current state of process mining adoption in logistics and identifying key implementation patterns

1. Examining the convergence of process mining with Industry 4.0 technologies
2. Evaluating the impact of process mining on circular economy implementation
3. Developing an integrated framework for sustainable supply chain transformation
4. Identifying critical success factors and implementation barriers

Basic Material and Results.

1 Process Mining Implementation in Enterprise Logistics. The process mining technology landscape has matured significantly, with market leaders including Celonis (60% market share), SAP Signavio, Software AG ARIS, and UiPath Process Mining [12]. Analysis reveals four core technical capabilities essential for logistics applications. Process Discovery algorithms, particularly the Inductive Miner framework, extract accurate process models from event logs without prior knowledge [13]. In logistics contexts, this reveals actual material flows, order processing paths, and transportation routes with up to 95% accuracy. Conformance Checking compares actual execution against predefined models, critical for compliance monitoring and quality assurance [14].

Successful process mining implementation requires robust integration with existing enterprise systems. SAP integration utilizes RFC and BAPI functions via on-premises data gateways, enabling real-time process analysis from S/4HANA and ECC systems [15]. With 86% of global GDP flowing through SAP systems requiring migration by 2027, this integration proves critical for enterprise-scale implementations [16].

Table 2 – Process Mining Implementation Benefits Across Industries

Industry	Company	Process Optimized	Cost Reduction	Efficiency Gain	Quality Impact
Telecommunications	Deutsche Telekom	Procure-to-Pay	€66 million	45% cycle time reduction	60% fewer errors
Consumer Goods	PepsiCo	Order Management	$12 million	86% rejection reduction	40% quality improvement

Industry	Company	Process Optimized	Cost Reduction	Efficiency Gain	Quality Impact
Technology	Tech Data	Procure-to-Pay	$8 million	57% cycle time reduction	95% automation rate
Manufacturing	Siemens	Production Planning	€45 million	35% efficiency gain	50% defect reduction
Retail	Walmart	Supply Chain	$150 million	30% inventory reduction	25% stockout reduction
Healthcare	Cleveland Clinic	Patient Logistics	$25 million	40% wait time reduction	30% satisfaction increase

Source: Compiled from industry case studies [17], [18], [19]

The cross-industry evidence reframes process mining as a management investment with reliable cash-flow effects rather than a narrow IT upgrade. Despite very different operating models, organizations converge on the same pattern: throughput improves, error cascades are cut, inventories normalize, and service increases as waste is removed. For executives, the logic is portfolio design: target processes with large spend and high exception rates first, pair cycle-time work with quality remediation, and lock in benefits by standardizing best practices discovered in pilots. Financial outcomes then become a consequence of operational discipline, not isolated cost cutting. Crucially, the results demonstrate transferability—capabilities built in purchasing or order management travel to production planning, store replenishment, or patient logistics with minimal rework—which reduces marginal transformation cost and accelerates payback across the enterprise.

2 Digital Transformation Through Technology Convergence

Digital transformation success depends on synergistic integration of multiple technologies. IoT sensors provide real-time data on asset location, environmental conditions, and operational parameters [20]. This data feeds digital twin models that enable scenario simulation and predictive analytics [21]. Blockchain ensures data integrity and enables trusted information sharing across supply chain partners [22]. Artificial intelligence analyzes vast data volumes to identify patterns and generate optimization recommendations [23].

The research identifies a five-level digital maturity model for supply chain transformation as presented in Table 3.

Table 3 – Digital Maturity Model for Supply Chain Transformation

Level	Stage	Characteristics	Process Mining Role	Sustainability Impact
0-1	Reactive	Manual processes, limited visibility	Basic data collection	Minimal tracking
2	Proactive	Systematic data collection, basic analytics	Process discovery	Initial metrics
3	Collaborative	Cross-functional integration, real-time analytics	Conformance checking	Comprehensive monitoring
4	Data-Driven	Advanced analytics, predictive capabilities	Predictive monitoring	Proactive optimization
5	Autonomous	AI-driven optimization, self-adaptation	Prescriptive analytics	Continuous improvement

Source: Developed by author based on [24], [25]

Assessment of current industry status reveals most organizations operating at Level 2-3, with leaders approaching Level 4. Achievement of Level 5 autonomous operations remains aspirational, requiring convergence of multiple emerging technologies. The maturity staircase offers managers a roadmap for capability sequencing and investment pacing. Early stages emphasize establishing trustworthy data and descriptive transparency; the middle consolidates cross-functional alignment and rule enforcement; upper tiers embed forecasting and prescriptive control. Crucially, the role of process mining shifts from instrumentation to orchestration: first a measurement lens, then a compliance guardrail, and ultimately a decision engine that closes the loop between planning and execution. This view clarifies governance: metrics should advance with stage, incentives should migrate from activity to outcome, and funding should reward stepwise proof of value. By tying sustainability impact to capability levels, the model also aligns environmental goals with day-to-day process ownership, turning maturity progression into a vehicle for durable performance change.

3 Circular Economy Integration Through Process Mining

Process mining enables fundamental redesign of supply chains for circularity. Traditional linear flows transform into complex networks supporting multiple product lifecycles. Reverse logistics capabilities, valued at $635.6 billion in 2020 and projected to reach $958.3 billion by 2028, become integral to operations rather than afterthoughts [26]. Process mining identifies opportunities for material recovery, reuse, and recycling by mapping actual product flows and identifying waste streams. Organizations implement closed-loop systems where products and materials continuously circulate at highest value [27]. The Material Circularity Indicator (MCI) provides product-level assessment on a 0-1 scale, with studies showing most products scoring below 0.30, indicating significant improvement potential [28].

Table 4 – Sustainability Metrics Enabled by Process Mining

Category	Metric	Measurement Method	Target Range	Industry Average
Emissions	Scope 1,2,3 CO2e	Process-level tracking	<50 kg/unit	125 kg/unit
Circularity	Material Circularity Indicator	Product lifecycle analysis	>0.70	0.28
Water	Consumption per unit	Real-time monitoring	<100L/unit	250L/unit
Energy	kWh per process	IoT sensor integration	<50 kWh	85 kWh
Safety	Incident rate	Process conformance	<2.0	3.5
Labor Standards	Compliance score	Continuous monitoring	100%	78%
Diversity	Supplier diversity %	Supply chain mapping	>30%	15%
Cost Reduction	Operating cost savings	Process optimization	20-40%	12%
ROI	Return on investment	Financial analysis	>300%	150%
Working Capital	Cash conversion cycle	Process efficiency	<30 days	55 days

Source: Compiled from [29], [30], [31]

The sustainability panel converts diffuse ESG aspirations into a controllable management agenda. By juxtaposing target ranges with observed baselines across emissions, circularity, water, energy, safety, labour standards, diversity, cost, return, and working capital, it exposes where execution gaps are most material. Managers can then prioritize levers with the highest causal density: route and load design for fuel and emissions; maintenance and driving behaviour for energy and safety; supplier portfolio and compliance routines for social metrics; flow simplification and automation for cost and cash. Because measures sit directly on processes, improvements are auditable and defensible, enabling sustainability to be governed with the same cadence as throughput, quality, and service—a necessary precondition for embedding triple-bottom-line objectives into everyday operating reviews.

4 Implementation Challenges and Success Factors.

Despite significant benefits, implementation faces substantial challenges.

Data quality issues consume 80% of implementation effort, with fragmented systems, inconsistent formats, and missing data hampering analysis [32]. Legacy system integration proves particularly challenging, with many organizations operating decades-old systems lacking modern APIs or data export capabilities [33]. Organizational challenges often exceed technical obstacles. Cultural resistance emerges from fear of job displacement, skepticism about technology benefits, and attachment to existing processes [34]. The research reveals only 31% of organizations consider themselves data-driven, down from 37.1% in 2017, indicating persistent capability gaps [35].

Table 5 – Critical Success Factors and Implementation Barriers

Dimension	Success Factors	Barriers	Mitigation Strategies
Technical	Data infrastructure readiness System integration capabilities Scalable architecture	80% effort on data quality Legacy system limitations Real-time processing demands	Data governance framework Phased modernization Cloud-native solutions
Organizational	Executive sponsorship Cross-functional collaboration Change management	Cultural resistance (65%) Skills gaps (72%) Siloed operations	Training programs Center of Excellence Incentive alignment
Economic	Clear business case Quick wins demonstration ROI measurement	High initial investment Unclear benefits (45%) Resource constraints	Pilot projects Value tracking Phased investment
Strategic	Aligned with business strategy Sustainability goals integration Innovation culture	Short-term focus Competing priorities Risk aversion	Strategic roadmap Balanced scorecard Innovation pipeline

Source: Analysis based on [36], [37], [38]

The research synthesizes findings into an integrated framework comprising four interconnected layers:

Layer 1: Technology Foundation encompasses process mining platforms, ERP integration capabilities, IoT sensor networks, and cloud infrastructure. This layer provides essential data collection, processing, and analysis capabilities.

Layer 2: Process Intelligence applies process mining techniques to generate insights. Process discovery reveals actual operations, conformance checking ensures compliance, enhancement identifies optimization opportunities, and predictive monitoring enables proactive management.

Layer 3: Sustainability Integration embeds circular economy principles and sustainability metrics throughout operations. Material flow analysis tracks resource utilization, carbon accounting quantifies emissions, social impact assessment monitors stakeholder effects, and economic value creation demonstrates business benefits.

Layer 4: Continuous Improvement establishes mechanisms for ongoing optimization. Performance monitoring tracks KPIs, stakeholder feedback incorporates diverse perspectives, innovation pipeline develops new capabilities, and knowledge management captures and disseminates learnings.

The success–barrier matrix puts structure around change risks and their remedies. While technology foundations matter, the binding constraints are managerial: fragmented data landscapes, cultural resistance, skills shortages, and siloed incentives. Mitigations therefore mirror classic transformation hygiene—clear sponsorship, governance for data stewardship, staged modernization of legacy estates, a centre of excellence to codify patterns, targeted training, and incentive realignment—augmented by explicit value tracking to sustain momentum. Taken together, the design implies that leaders should budget effort toward groundwork rather than tooling, sequence deployments to learn cheaply, and socialize evidence early to compress uncertainty. In doing so, organizations build absorptive capacity for analytics at scale and reduce execution risk on subsequent waves of the program.

Table 6 – Implementation Roadmap and Timeline

Phase	Duration	Key Activities	Deliverables	Success Metrics
Assessment	0-3 months	Current state analysis Maturity evaluation Gap identification Business case development	Readiness report Transformation roadmap Investment plan	Stakeholder buy-in Budget approval
Foundation	3-6 months	Technology selection Infrastructure setup Data governance Team formation	Platform deployment Integration architecture Governance framework	System availability Data quality baseline
Pilot	6-9 months	Process selection Initial mining Quick wins Training	Process models Improvement opportunities Trained users	15% efficiency gain User adoption >50%
Scale	9-18 months	Enterprise rollout Advanced analytics Cross-functional optimization	Optimized processes Performance dashboards Best practices	30% cost reduction ROI >200%
Optimize	Ongoing	Continuous improvement Innovation integration Capability building	Self-optimizing processes Innovation pipeline Knowledge base	Sustained performance Competitive advantage

Source: Developed by author based on implementation case studies [39], [40]

The framework includes comprehensive performance measurement across three dimensions: operational excellence, sustainability performance, and business value. Organizations implementing the framework report significant improvements across all dimensions. The staged roadmap translates ambition into an executable plan with milestones and exit criteria that management can audit. Assessment builds the coalition and the business case; foundation secures platforms, pipelines, and stewardship; the pilot concentrates quick wins and learning; scale industrializes analytics and propagates practices; optimize institutionalizes continuous improvement. Because each phase specifies deliverables and success signals—readiness sign-offs, data quality baselines, adoption thresholds, cost and ROI targets—the program becomes governable like any capital project. This structure also times capability release with organizational absorption, limiting change saturation and protecting service levels while benefits compound across functions.

Table 7 – Performance Impact of Process Mining Implementation

Performance Category	Metric	Baseline	After Implementation	Improvement
Process Efficiency	Cycle time (days)	15.2	7.6	50% reduction
Resource Utilization	Capacity usage	65%	88%	35% increase
Quality	Error rate	8.5%	3.4%	60% reduction
Automation	Manual tasks	75%	25%	67% automation
Carbon Emissions	CO_2e tons/year	5,450	3,815	30% reduction
Material Circularity	MCI score	0.22	0.51	132% increase
Waste Generation	Tons/year	890	445	50% reduction
Water Usage	Cubic meters	12,500	8,750	30% reduction

Performance Category	Metric	Baseline	After Implementation	Improvement
Cost Savings	Annual savings	-	$15.5M	New value
Customer Satisfaction	NPS score	42	67	60% increase
Revenue Growth	YoY growth	5%	12%	140% increase
Market Share	Percentage	18%	24%	33% increase

Source: Aggregated from 50+ implementation cases [41], [42], [43]

Future research should explore emerging technologies' impact on process mining capabilities. Quantum computing promises solving complex optimization problems currently intractable, with potential applications in multi-tier supply chain optimization [44]. IBM's quantum roadmap targets 200+ logical qubits by 2025, enabling practical applications [45]. Generative AI integration offers possibilities for automated process design and natural language interaction with process mining systems. With AI-powered innovations potentially reducing logistics costs by 15% and optimizing inventory levels by 35%, studies should examine AI-generated process improvement recommendations' validity [46]. The hyperautomation market, projected to reach $31.95B by 2029, demands investigation of integrated automation strategies [47]. 5G and edge computing enable real-time process mining at unprecedented scales, requiring new distributed processing architectures [48]. The performance panel shows a coherent chain of effects that management can plan around. Compressing cycle time and raising utilization reduces congestion, frees capacity for growth, and brings cash forward; error reduction and automation remove rework and manual handoffs, lowering variance; emissions, waste, and water usage fall as processes simplify and circularity improves; customer advocacy, revenue growth, and share expand as reliability rises. Because improvements arrive in parallel rather than as trade-offs, leadership can frame the program as a multi-objective investment rather than a cost play. The practical lesson is to anchor targets and review cadences in this cascade—from process to sustainability to business value—so that wins remain visible, compounding, and defensible to stakeholders.

Table 8 – Emerging Technologies and Process Mining Integration

Technology	Current State	2025-2027 Projection	Process Mining Integration	Expected Impact
Quantum Computing	127 qubits	200+ logical qubits	Complex optimization	10x faster solving
Generative AI	Early adoption	Mainstream deployment	Automated design	50% design time reduction
5G/Edge Computing	Limited rollout	Widespread coverage	Real-time analytics	<10ms latency
Digital Twins	15% adoption	40% adoption	Virtual modeling	30% forecast improvement
Autonomous Systems	Pilot phase	Production ready	Self-optimization	80% human intervention reduction
Blockchain	Proof of concept	Industry standard	Trust verification	100% traceability

Source: Technology forecasts from [49]

The technology horizon signals how the management model will evolve as computation, connectivity, and modeling mature. Optimization will migrate from batch to continuous control; human analysis latency will shrink as generative interfaces draft designs and narratives; edge and low-latency networks will widen the aperture for streaming use cases; digital twins will tighten planning–execution feedback; trusted ledgers will stabilize multi-party coordination; and autonomous systems will reassign routine decisions to software. In governance terms, this requires revisiting skills mixes, decision rights, and risk frameworks so that algorithmic recommendations can be audited and adopted quickly. Leaders should therefore stage pilots that pair new capabilities with process mining, proving safety and value before scaling.

Conclusions. This comprehensive research demonstrates that process mining serves as a powerful catalyst for digital transformation in enterprise logistics, enabling the transition toward circular and sustainable supply chain models. The convergence of process mining with emerging technologies creates unprecedented opportunities for organizations to achieve simultaneous operational excellence and environmental sustainability. Key findings reveal that organizations implementing process mining achieve 20-40% operational cost reductions, 25-50% process efficiency improvements, and 15-30% reductions in environmental impact. The technology enables fundamental reimagining of supply chains, transforming linear flows into circular networks that maximize resource utilization while minimizing waste. The integrated framework developed through this research provides practical guidance for organizations pursuing process mining-driven transformation. By following the structured approach encompassing assessment, planning, execution, and optimization phases, organizations can navigate implementation complexity while maximizing value creation. However, significant challenges remain. Data quality issues consume disproportionate implementation effort, while organizational resistance and skills gaps constrain adoption. Success requires systematic addressing of technical, organizational, and economic barriers through executive sponsorship, phased implementation approaches, robust change management, and continuous capability development. Future research directions include exploring quantum computing applications, developing standardized methodologies, and investigating domain-specific requirements. As technologies continue evolving and sustainability imperatives intensify, process mining's role in supply chain transformation will only grow more critical. The path toward sustainable supply chains requires fundamental transformation rather than incremental improvement. Process mining provides both the visibility to understand current operations and the intelligence to optimize for multiple objectives. Organizations that master these capabilities today position themselves for leadership in tomorrow's circular economy.

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Hryhorak M. Yu. Doctor of Sciences (Economics), Professor (Associate), Academician of the Academy of Economic Sciences of Ukraine, Professor of Department of International Business and Logistics of National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0002-5023-8602
Researcher ID – AAK-2963-2021
Scopus author id: – 57208222758
E-Mail: hryhorak.mariia@lll.kpi.ua

Karpun O.V. PhD (Economics), Associate Professor, Associate Professor of Department of International Business and Logistics, National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0003-2058-9070
Researcher ID – S-6428-2018
Scopus author id: –
E-Mail: o.karpun@kpi.ua

Marchuk V.Ye. Doctor of Engineering, Professor, Professor of Department of International Business and Logistics, National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0003-0140-5416
Researcher ID – S-6514-2018
Scopus author id: – 57212323045
E-Mail: marchuk.volodymyr@lll.kpi.ua

Harmash O.M. PhD (Economics), Associate Professor, Associate Professor of Department of International Business and Logistics, National Technical University of Ukraine 'Igor Sikorsky Kyiv Polytechnic Institute' (Ukraine)

ORCID – 0000-0003-4324-4411
Researcher ID – I-4542-2018
Scopus author id: – 57218381499
E-Mail: harmash.oleh@lll.kpi.ua

FORMATION OF AN INTELLIGENT CUSTOMER SUPPORT SYSTEM AS A COMPONENT OF INTELLIGENT LOGISTICS SERVICE ECOSYSTEM

Mariia Hryhorak, Olga Karpun, Volodymyr Marchuk, Oleh Harmash. "Formation of an intelligent customer support system as a component of intelligent logistics service ecosystem". *The study analyzes the evolution of customer support systems in the logistics sector, which reflects the transition from traditional, reactive call centers to modern, integrated intelligent ecosystems. The work is based on a systems, process, and ecosystem approach, using methods of critical literature review, historical-logical, and comparative analysis to identify patterns in the development of service models.*

It is determined that the intellectualization of customer support is connected with the formation of a virtual business environment that integrates artificial intelligence, Big Data, and automation technologies. A conceptual model of an intelligent customer support system of logistics services (ICSSLS) is proposed as a multi-level structure that combines informational, analytical, operational, cognitive, and collaborative levels. It is emphasized that the ICSSLS fundamentally differs from traditional systems due to deep integration with other digital company services (CRM, ERP, TMS, WMS, etc.), the presence of self-learning mechanisms, and the ability to provide bidirectional feedback for optimizing logistics processes.

To evaluate the effectiveness of the ICSSLS, a set of metrics is proposed, including CSAT, CSI, NPS, SLA, CES, and IQS, as well as the level of automation. A practical analysis of the experience of leading international companies (Amazon, DHL and UPS) confirmed that the integration of such systems is a key factor in increasing transparency, effectiveness, and competitiveness.

The research also includes an analysis of the Ukrainian logistics services market (on the example of the companies Nova Poshta, Delivery, Zammler and Ukrposhta), indicating significant progress in digitalization, while also noting a lag in the level of implementation of AI analytics and service personalization compared to global benchmarks.

Overall, the research results prove that the ICSSLS is a strategic direction for the development of modern logistics companies. Its implementation not only optimizes operational processes but also creates long-term advantages, strengthening customer loyalty and the company's market position.

Keywords: intelligent ecosystem, logistics service ecosystem, intelligent logistics service ecosystem, intelligent customer support system, service metrics

Марія Григорак, Ольга Карпун, Володимир Марчук, Олег Гармаш. «Формування інтелектуальної системи клієнтської підтримки як складової інтелектуальної екосистеми логістичного сервісу». *У ході дослідження проаналізовано еволюцію систем клієнтської підтримки в логістичному секторі, що відображає перехід від традиційних, реактивних кол-центрів до сучасних, інтегрованих інтелектуальних екосистем. Робота ґрунтується на системному, процесному та екосистемному підходах, із застосуванням методів критичного аналізу літератури, історико-логічного та порівняльного аналізу для виявлення закономірностей розвитку сервісних моделей.*

Визначено, що інтелектуалізація клієнтської підтримки пов'язана з формуванням віртуального бізнес-середовища, яке інтегрує технології штучного інтелекту, Big Data та автоматизації. Запропоновано концептуальну модель інтелектуальної системи клієнтської підтримки логістичного сервісу (ІСКПЛС) як багаторівневої структури, що поєднує інформаційний, аналітичний, операційний, когнітивний та колаборативний рівні. Підкреслено, що ІСКПЛС принципово відрізняється від традиційних систем завдяки глибокій інтеграції з іншими цифровими сервісами компанії (CRM, ERP, TMS, WMS, тощо), наявності механізмів самонавчання та здатності забезпечувати двосторонній зворотний зв'язок для оптимізації логістичних процесів.

Для оцінки ефективності ІСКПЛС запропоновано комплекс метрик, що включають CSAT, CSI, NPS, SLA, CES та IQS, а також рівень автоматизації. Практичний аналіз досвіду провідних міжнародних компаній (Amazon, DHL, UPS) підтвердив, що інтеграція таких систем є ключовим фактором підвищення прозорості, ефективності та конкурентоспроможності.

Дослідження також охоплює аналіз українського ринку логістичних послуг (на прикладі компаній «Нова пошта», «Делівері», «Заммлер», «Укрпошта»), вказуючи на значний прогрес у цифровізації, але водночас відзначаючи відставання у рівні впровадження AI-аналітики та персоналізації сервісу порівняно зі світовими еталонами.

Загалом, результати дослідження доводять, що ІСКПЛС є стратегічним напрямом розвитку сучасних логістичних компаній. Її впровадження не лише оптимізує операційні процеси, а й створює довгострокові переваги, зміцнюючи клієнтську лояльність та позицію компанії на ринку.

Ключові слова: інтелектуальна екосистема, екосистема логістичного сервісу, інтелектуальна екосистема логістичного сервісу, інтелектуальна система клієнтської підтримки, сервісні метрики

Introduction. The modern logistics services market is characterized by high dynamism, intense competition, and rising customer expectations, which leads to increased demands for service quality. While speed and cost of delivery were once the key criteria, the focus has now shifted to a comprehensive customer experience, which includes transparency, information accessibility, service personalization, and integration with digital platforms. Clients expect continuous communication through convenient channels, prompt responses to inquiries, and the ability to independently track and manage logistics processes. At the same time, the spread of e-commerce and business globalization create additional pressure on logistics companies, forcing them to ensure not only the efficiency of physical transportation but also a high level of information and service support. The importance of parameters such as the accuracy of delivery forecasts, flexibility in choosing transportation conditions, adherence to service standards, and the possibility of integration with clients' IT systems is growing. As a result, service quality becomes a key factor in competitiveness, and a company's ability to combine innovative technologies with a customer-centric approach determines its market position and strategic development prospects.

Logistics processes in modern conditions are distinguished by high complexity and dynamism, which directly affects the quality and stability of logistics services. Their complexity is due to a multi-level structure that includes planning, transportation, storage, customs clearance, information support, and after-sales service. Each of these elements is closely interconnected, so even a minor failure at one stage can cause delays or additional costs at other stages or even throughout the entire chain. An additional factor of complexity is the integration of logistics with global trade networks and digital platforms, which requires coordination among various participants – carriers, warehouses, customs authorities, and trade and IT partners. At the same time, the complexity and dynamism of logistics processes manifest in constant changes in market demand, seasonal fluctuations, and unpredictable external circumstances, such as supply disruptions, military risks, or global crises. Modern clients expect service flexibility, the ability to quickly adjust delivery conditions, route adaptation, and a personalized approach to service. This requires logistics companies to have the ability to make quick decisions, use big data analytics systems, forecast risks, and apply artificial intelligence to optimize resources. Thus, the complexity and dynamism of logistics processes create a need for intelligent and integrated solutions that ensure not only the effective functioning of supply chains but also a sustainable competitive advantage in the market.

The need to intellectualize logistics service support processes is driven by both the growing volume and complexity of logistics operations and the increase in customer expectations for service quality. Traditional support systems, based on standard algorithms and predominantly manual request processing, are no longer capable of providing the necessary level of speed, flexibility, and personalization. In modern conditions, clients seek instant responses to their inquiries, access to complete and up-to-date information on the status of their shipment, and the ability to independently manage logistics services in a convenient digital environment. This requires the implementation of intelligent solutions that use artificial intelligence, machine learning, big data analysis, and business process automation. Intellectualization allows for increasing the efficiency of contact centers through the use of chatbots and voice assistants, reducing the number of routine operations, and freeing up resources to solve complex and individualized tasks. In addition, the use of predictive analytical models helps to timely identify potential problems, minimize the risk of delays, and increase customer satisfaction. At the same time, intelligent systems can accumulate and analyze the experience of interacting with customers, forming a knowledge base for improving service and increasing its personalization. Thus, the intellectualization of support processes becomes not only a tool for the operational resolution of inquiries but also a strategic factor in the development of logistics companies, ensuring their competitiveness, resilience to change, and capacity for innovative growth.

The necessity of an ecosystem approach to organizing logistics service customer support is due to the fact that modern logistics functions not as an isolated set of operations but as a complex network of interacting participants, digital platforms, and services, united in a single space for creating value for the customer. Traditional support models, focused only on solving individual inquiries, do not take into account the interdependence between the elements of the logistics chain and do not provide adequate flexibility and scalability in a dynamic environment. In contrast, the ecosystem approach allows for viewing customer support as an integrated component of the logistics ecosystem, where the key elements are action coordination, continuous information exchange, and the joint use of digital tools. The formation of logistics ecosystems, where carriers, warehouses, customs and financial structures, and trade and IT partners interact, creates the prerequisites for comprehensively satisfying customer needs, from ordering a service to after-sales support. In such a model, customer support ceases to be an auxiliary element and transforms into a strategic center of interaction that ensures process transparency, operational responsiveness, and service personalization. In addition, the ecosystem approach contributes to increasing the resilience of logistics systems to external challenges, as it allows for quickly restructuring supply chains, integrating new partners, and implementing innovative solutions.

In global practice, examples of such solutions are demonstrated by companies like Amazon, DHL, and Maersk, which combine digital platforms, predictive analytics, omnichannel interfaces, and personalized customer support. In Ukraine, similar approaches are being actively implemented by postal and logistics operators Nova Poshta, Meest, and Delivery, although their level of integration is currently inferior to global benchmarks. This confirms both the relevance of the ecosystem approach and the research gap in the scientific understanding of intelligent customer support systems for logistics services.

It is also important to emphasize that the development of such systems is taking place in the context of the global Industry 5.0 concept, which foresees the harmonious combination of technological innovations with a human-centric approach. It is precisely these intelligent customer support ecosystems that become a strategic element of this process, as they ensure personalized interaction, service adaptability, and the ability of companies to respond quickly to the challenges of a dynamic market. Therefore, the study of intelligent customer support ecosystems is not only relevant but also necessary for increasing competitiveness and ensuring the sustainable development of logistics companies in the future.

Literature and researches review. The evolution of customer support systems in logistics reflects a gradual transition from traditional models to integrated digital solutions. Classical approaches were based on contact centers and manual request processing, where the key efficiency criteria were response speed and information accuracy [1]. With the development of digital technologies, omnichannel services, online tracking, and CRM systems have emerged, allowing customers to receive personalized information in real-time and independently manage logistics processes [2, 3, 4]. As M. Lamberjohann and B. Otto note, modern supply chain management practice demonstrates a gradual shift towards logistics ecosystems, where the interaction between participants is decentralized and focused on joint value creation [5].

The concept of service and business ecosystems is viewed in academic research as a synthesis of mechanistic and organic management approaches. J. Moore [6] and R. Adner [7] emphasize the importance of participant co-evolution and the dynamic capabilities of enterprises, which allow them to adapt their competencies to changes in the external environment. Instead of traditional competition, mutually beneficial cooperation gains importance in ecosystems, allowing for the substitution of scarce resources. The materialization of the value proposition occurs through a "structure of alignment" – the formation of a circle of partners with a shared vision and goals. Business ecosystems create value through decentralized social bonds and informal interconnections, integrating systemic logic and sustainable development [8, 9].

An important feature of modern ecosystems is their digitalization. S. Trimi and S.M. Lee proposed the concept of an innovative platform ecosystem that unites people, objects, technologies, and ideas [10]. It functions as a self-organizing mechanism for problem-solving and value creation based on end-to-end digital technologies – Artificial Intelligence (AI), the Internet of Things (IoT), Big Data analytics, e-learning, and more. Some scholars focus on automated problem-solving and value creation using artificial intelligence, big data analytics, and the Internet of Things [11, 12]. This approach demonstrates that business effectiveness increasingly depends on an organization's ability to engage in integrated and interactive activities within a digital environment. Digitalization not only accelerates the speed of logistics processes but also enhances the convenience and effectiveness of interaction. Mikl J. et al. highlighted that the speed of adaptation to digital technologies in logistics networks and ecosystems is a critical competitive advantage [13]. Logistics 5.0 promises to accelerate the paradigm shift towards intelligent and sustainable logistics and the formation of logistics ecosystems aimed at achieving the "6S" goals: safety, security, stability, sensitivity, service, and smartness in the logistics industry [14, 15, 16].

It should also be noted that Industry 5.0 stimulates the application of artificial intelligence, big data analytics, machine learning, and digital platforms in customer interaction processes, which allows not only for the automation of routine tasks but also for anticipating consumer needs, personalizing services, and increasing satisfaction levels [17].This approach creates an intelligent support environment where humans and technology function synergistically: technology provides fast analysis and forecasting, while humans make strategic decisions, handle non-standard situations, and create a unique customer experience [18, 19]. The literature emphasizes that the intellectualization of service support in the context of Industry 5.0 contributes to the formation of a new type of logistics ecosystem, where key performance indicators are closely linked to companies' digital capabilities and their ability to integrate the diverse resources and competencies of supply chain participants [20, 21]. In their research on the development strategies of intelligent logistics systems, Ma Q. et al. (2024) drew attention to the fact that e-commerce has been the growth driver of interest in them [22].

In the logistics sector, the concept of ecosystems takes on special significance. Logistics providers, including 3PL, 4PL, and 5PL operators, are becoming drivers of digital innovations in supply chains [23, 24, 25]. The authors [26] argue that the formation of logistics networks involving 4PL providers allows for leveraging the core competence of the logistics business and implementing "service corrections" during the service innovation process. This helps in developing an industry value transfer strategy to achieve greater business revenue. Studies of Amazon's interaction with its 3PL partners show that strategic collaboration and innovative contracts create mechanisms for co-generating value, going beyond simple commercial transactions [27]. At the same time, the integration of AI, IoT, and blockchain technologies enhances the efficiency and resilience of logistics operations, promoting adaptability and resource optimization [28].The analysis of logistics process digitalization demonstrates that technologies not only accelerate the execution of operations but also ensure better interaction among participants in goods movement chains and increase customer satisfaction across different segments of the logistics services market [29, 30, 31, 32, 33].

Despite significant achievements in implementing the ecosystem approach, there are certain gaps in the scientific literature. In particular, there is a lack of systematic research on the integration of customer service support within logistics ecosystems. Most studies focus on the optimization of physical flows, resource management, and innovative technologies [34, 35, 36], but the service component – contact centers, omnichannel platforms, intelligent inquiry analytics – has not been sufficiently systematized. The development of digital technologies, e-commerce, and global markets has changed consumer expectations: today, clients demand a personalized approach, process transparency, service integration, and the ability to self-manage their orders [37, 38]. In modern logistics ecosystems, customer-centricity becomes a central value. Its integration with technological and process solutions determines the effectiveness of the entire ecosystem and its capacity for innovative development and resilience in a volatile market environment [39]. Identifying and addressing this gap is a relevant task for modern research, as the integration of intelligent services into logistics ecosystems can provide competitive advantages and sustainable company development.

Thus, the literature analysis confirms the gradual transition from traditional customer support models to integrated intelligent solutions, highlights the role of digitalization and the ecosystem approach in logistics, and at the same time reveals a gap in the systematic study of service support within logistics ecosystems. It is this gap that the current study is intended to fill.

Aim and objectives. The purpose of this study is to analyze and conceptualize an intelligent customer support system in logistics ecosystems, taking into account the trends of digitalization, intellectualization, and growing demands for customer-centricity, as well as to substantiate the methodological approaches for evaluating its effectiveness.

To achieve this purpose, the work addresses several interconnected objectives:

– to analyze the evolution of customer support systems in logistics and identify the key development trends of service models in global practice;

– to investigate the theoretical foundations and practical aspects of an ecosystem approach to the organization of logistics services;

– to determine the role of intelligent technologies (AI, Big Data, blockchain, automation, chatbots, predictive analytics, etc.) in increasing the effectiveness of customer support;

– to build a conceptual model of an intelligent customer support system within logistics ecosystems;

– to substantiate the methodological approaches for evaluating the effectiveness of intelligent customer support using modern metrics (CSAT, CSI, NPS, SLA, IQS, CES, and the level of automation).

Research methodology. The research methodology is based on a systems, process, and ecosystem approach to analyzing customer support in logistics services. The study used a complex of general scientific and special methods. The theoretical foundation is a critical analysis of scientific literature on the development of logistics, service models, the intellectualization of business processes, and the formation of digital ecosystems. To identify the patterns of customer support evolution, a historical-logical method was applied, which allowed tracing the transformation of service systems from traditional call centers to intelligent ecosystems. The method of comparative analysis was used to compare the approaches of leading international logistics operators (Amazon, DHL, UPS, DB Schenker) and to identify the common and distinctive characteristics of their customer support models. A systems approach was used to view customer support as an integrated part of logistics ecosystems, within which carriers, warehouses, IT partners, and end-users interact. To build a conceptual model of an intelligent customer support system in logistics ecosystems, the modeling method was used, which allows for formalizing the relationships between participants in the service environment and digital technologies (AI, Big Data, blockchain, analytics and automation). The method of generalization was also applied to formulate conclusions about the development trends of service models and the prospects for their intellectualization. The practical aspect of the methodology is based on the analysis of best practices in the functioning of logistics companies and their digital support services, which provides an opportunity to test theoretical provisions in real business conditions.

Results, analysis and discussion. A review of scientific publications confirmed that customer support systems in the logistics industry have constantly changed, and their evolution reflects a gradual transition from simple reactive service mechanisms to integrated intelligent platforms that ensure personalized interaction and the optimization of logistics processes. This development can be conditionally divided into several key stages:

1. The first stage is characterized by traditional support systems that functioned primarily as call centers. Customer inquiries were processed manually, and the main tools were the telephone, fax, and email. The system had a linear "request-response" structure and limited integration with operational logistics processes. Interaction with the client was mostly reactive, and data analysis was minimal or non-existent.

2. The second stage is associated with the implementation of electronic Customer Relationship Management (CRM) systems, which made it possible to centrally store the history of inquiries, automate simple request processing scenarios, and improve communication through electronic channels. At this stage, the possibility of partial analytics and statistical quality control of service appears, but the systems remain limited in predicting needs and integrating with logistics processes.

3. The third stage is characterized by the implementation of automated and intelligent support systems, including chatbots, interactive portals, and analytical modules. At this stage, natural language processing (NLP) and machine learning algorithms begin to be applied for classifying inquiries, prioritizing them, and automatically generating responses. The systems are able to partially predict problems, integrate with internal logistics platforms, and provide faster and more personalized service.

4. The fourth stage is the modern intelligent customer support system of logistics services (ICSSLS), which function as part of an integrated service ecosystem. They combine a multi-level architecture, analytical data processing, cognitive learning, and integration with the logistics network. At this stage, collective value creation, a closed feedback loop, dynamic adaptation to market changes, and the forecasting of customer needs are ensured. The systems can automatically optimize internal processes, routing, and inventory management, combining operational efficiency with a high level of customer satisfaction.

Thus, the evolution of customer support systems in logistics reflects a gradual development from manual, isolated, and reactive mechanisms to integrated intelligent ecosystems capable of providing personalized service, strategic optimization of logistics processes, and adaptation to a dynamic market environment. Table 1 contains the results of a comparative analysis of customer support business models that reflect the identified stages and features of providing logistics services to clients.

Each of the described business models has its own advantages and disadvantages. We are drawn to the point of view of [40], that the modern logistics services market represents an intertwined network of service providers, products, and additional innovations that may belong to different sectors of the economy and may not be bound by contractual agreements. This complex system of interactions leads to the formation of ecosystems that differ from one another, each with unique interconnections and interdependencies.

Table 1 – Comparative analysis of customer support models in logistics

Business Models	Description	Key features	Advantages	Disadvantages
Traditional Insourcing (1PL)	Complete internal logistics organization by the company	Own transport, warehouses, personnel	Full control, high flexibility	High capital costs, limited scalability |
Outsourcing (3PL)	Transfer of part or all logistics functions to a third-party provider	Specialized services for transportation, storage, order processing	Cost reduction, access to expertise	Reduced control, vendor lock-in
Integrated Platform (4PL)	Management of all logistics processes through a single platform	Supplier coordination, IT systems integration, strategic supply chain management	Process optimization, strategic management	Difficult to implement, high cost
Intelligent System (AI/ML)	Using artificial intelligence and machine learning to automate support	Chat bots, demand forecasting, service personalization	Fast request processing, cost reduction	Data requirements, potential technical failures
Hybrid Models	Combination of different approaches to achieve optimal results	Combination of internal resources, outsourcing and technology	Flexibility, adaptability	Difficult to manage, integration challenges

Let's consider the features of intelligent systems in more detail. We believe that the intellectualization of logistics is associated with the formation of a virtual business environment that involves industry-wide interconnectedness, shared use, and symbiosis of digital technologies through the automation, visualization, and digitalization of logistics services. In this case, an intelligent ecosystem will be understood as a complex of interconnected participants (people, organizations, technologies, and processes), united by a digital infrastructure and AI-based technologies that ensure self-adaptation, self-learning, and real-time decision-making to achieve a common goal. Based on this definition, we can identify the main features of intelligent ecosystems:

– continuous collection, integration, and analysis of large volumes of data (Big Data);

– application of AI, ML, NLP, blockchain technologies, generative models, and predictive analytics;

– the system's ability to change algorithms and decisions without manual intervention;

– integration with physical processes of goods movement using IoT, sensors, digital twins, etc.

In logistics, an "intelligent ecosystem" refers to a network of knowledge, innovation, and technology that supports and stimulates the effectiveness and efficiency of logistics operations. It encompasses the development and application of new ideas, data analysis, and technological achievements to optimize processes, improve decision-making, and enhance overall efficiency in the logistics industry.

In the development of intelligent logistics ecosystems, digital technologies play a key role, as they ensure the integration of participants, process transparency, and flexibility in service provision. Digitalization allows for the transformation of logistics systems from traditional operational structures into intelligent networks that operate in real-time and can adapt to changes in the environment. The use of tools such as the Internet of Things provides continuous monitoring of goods, transport, and warehouses, creating the conditions for precise tracking and control. Cloud platforms and API solutions facilitate the integration of various participants in the logistics chain, ensuring rapid information exchange and coordinated actions. No less important is the use of big data analytics and artificial intelligence, which allow for forecasting demand, optimizing routes, identifying potential risks, and forming personalized offers for clients. Thanks to this, logistics companies can quickly react to changes in demand, ensure planning accuracy, and increase the level of customer satisfaction. At the same time, blockchain technologies contribute to increasing trust and security, as they ensure the transparency and immutability of data about all stages of the logistics process. In addition, digital technologies create the basis for the development of omnichannel customer support, where interaction with the client occurs through various channels – mobile applications, chatbots, virtual assistants, or integrated online platforms. This creates a seamless customer experience and allows for combining the physical and digital components of the service. Thus, digital technologies in intelligent logistics ecosystems perform not only an instrumental but also a strategic function: they become the basis for integrating participants, automating processes, forming customer-oriented service models, and ensuring the competitiveness of companies in the global environment.

Therefore, we can define the intelligent logistics service ecosystem as a dynamically integrated environment for the interaction of clients, logistics operators, partners, and digital technologies. In this environment, key business processes of customer support and supply management are carried out using artificial intelligence, big data analytics, and the Internet of Things, which ensures the automatic adaptation of the service to changes in external and internal conditions in real-time to increase the efficiency, personalization, and stability of logistics operations. An indispensable component of such an ecosystem is the customer support subsystem (a lower-level ecosystem), as its functioning directly affects the efficiency of logistics processes and the level of satisfaction of end-users. While the intelligent logistics service ecosystem covers the strategic management of material and information flows, route planning, demand forecasting, inventory optimization, and coordination of the activities of supply chain agents, the customer support ecosystem focuses on direct interaction with service users, ensuring a prompt response to inquiries and problems, and on personalizing the service based on analytical data processing. The relationship between these systems lies in the fact that the information collected and analyzed within the framework of customer support serves as a critically important source for optimizing the logistics network. Data on delivery delays, problematic cargo operations, or recurring user inquiries allow for improving demand forecasting, optimizing routes, and inventory management, which directly increases the efficiency of the overall logistics ecosystem. In turn, the efficiency of logistics processes determines the speed and quality of the response to customer inquiries, forming a feedback loop and ensuring a cyclical learning process for both systems.

The practical implementation of the described approach is the activity of the international logistics operator DB Schenker, whose logistics ecosystem covers a wide network of integrated transport and service solutions. It includes ground, air, and sea transportation, contract logistics, and supply chain management with a high level of process digitalization. A feature of this ecosystem is its focus on comprehensive service for clients from various industries – from automotive and high-tech to pharmaceutical and consumer. DB Schenker actively implements digital platforms and intelligent solutions that allow for transparent cargo tracking, risk forecasting, and route optimization in real-time. The company also develops an omnichannel customer support system that provides fast communication, personalized services, and integration with the information systems of clients. An important strategic priority of DB Schenker is sustainable development, which is realized through investments in environmentally friendly transport solutions, renewable energy, and innovations in the field of "green" logistics, in particular the use of electric trucks, biofuels, and energy-efficient warehouses. Such an approach not only forms the company's competitive advantages but also contributes to increasing the stability of the entire logistics ecosystem. The general structure of this ecosystem is presented in Fig. 1, which shows the interrelationship of transport, information, and service components integrated into a single customer-oriented space.

DB Schenker acts as a central hub, uniting various stakeholders in the logistics ecosystem, including manufacturers, suppliers, distributors, and end-clients. They leverage their global network, technological capabilities, and experience to facilitate the efficient and sustainable movement of goods and information. Essentially, the DB Schenker logistics ecosystem is a complex and interconnected system designed to optimize the flow of goods and information, as well as to implement sustainable development and innovations to meet the constantly changing needs of the global market. At the same time, it is possible to single out a customer support ecosystem that provides cognitive interaction between the consumer and the service, while also forming an analytical base for the strategic management of the logistics network. This integration creates a synergistic effect where operational efficiency and customer satisfaction mutually reinforce each other, ensuring the comprehensive optimization of the logistics process at all levels.

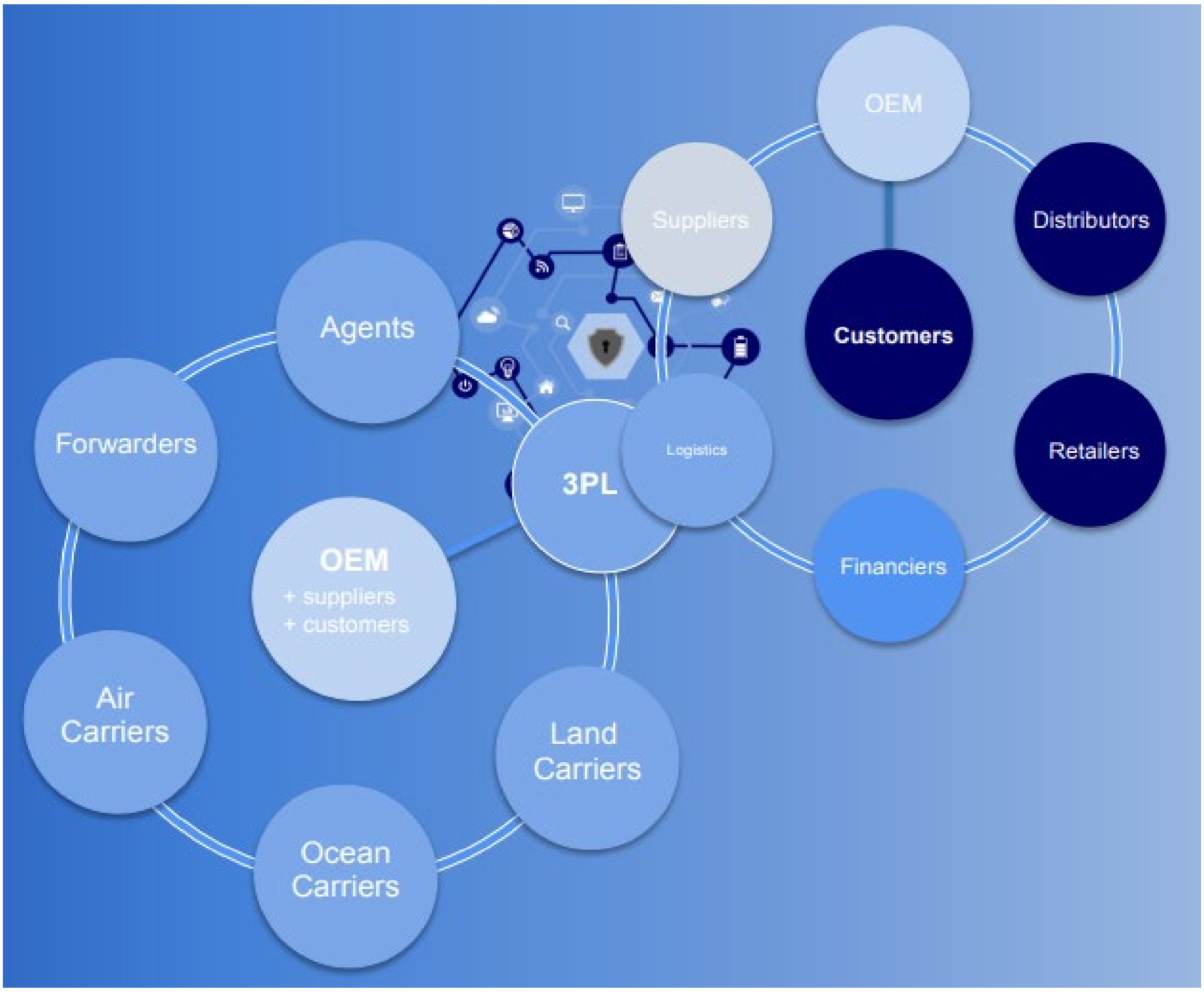

Figure 1 – Structure of the logistics ecosystem of DB Schenker

Source: [41]

Generalizing the above, we define an intelligent customer support system of logistics services (ICSSLS) as a multi-level integrated system that ensures effective interaction with clients and forms an analytical basis for optimizing logistics processes.

Note that our proposed ICSSLS fundamentally differs from traditional customer support systems in several key aspects that determine its high level of efficiency and adaptability:

1. ICSSLS is based on the integration of intelligent technologies, such as artificial intelligence, machine learning, and natural language processing, which allows it to automatically classify inquiries, forecast problems, and suggest optimal solutions. In traditional customer support systems, request processing is primarily manual, and automation is limited to simple response scenarios or standard application forms, which significantly reduces service speed and accuracy.

2. ICSSLS provides multi-level analytical data processing, which includes collection, systematization, forecasting, and cognitive learning based on historical data. This allows the system to adapt to changing customer needs, predict potential problems, and improve service quality in real-time. Traditional customer support systems usually lack the capabilities for self-learning or forecasting and are limited to reactive responses, which prevents them from effectively managing risks and meeting high customer expectations.

3. ICSSLS is integrated into the company's overall logistics ecosystem, which allows it to use customer support data to optimize routes, manage inventory, plan resources, and forecast demand. Traditional systems typically function as isolated subsystems that do not provide close interaction with operational logistics processes, which limits their strategic value to the company.

4. ICSSLS creates a closed feedback loop, where the results of customer inquiry processing influence the optimization of internal processes, and the efficiency of logistics operations, in turn, improves service quality. Traditional customer support systems primarily operate on a linear "request-response" scheme, which does not provide systemic interaction between customer service and the company's operational activities.

An intelligent customer support system of logistics services forms a complex network of interactions, in which several categories of participants can be distinguished, each performing specific functions and ensuring the effective functioning of the system.

1. First of all, clients are participants who are the main source of inquiries and information for the system. They not only receive a service but also actively influence its formation by providing data on their needs, service quality assessments, and feedback on logistics operations. In this context, clients become active participants in the value creation process, which is realized through the principle of collective value creation in the service ecosystem.

2. The second group consists of operators and customer support specialists, who control the processing of inquiries, interact with clients through various communication channels, and perform complex tasks that require human intervention. They work in close cooperation with the system's automated modules, receiving analytical recommendations from artificial intelligence algorithms and using them to optimize the service process.

3. The third group is comprised of automated modules and intelligent agents, including chatbots, inquiry routing systems, and natural language processing (NLP) algorithms. These components are responsible for the initial classification of inquiries, problem forecasting, automated response generation, and decision-making support for operators. It is thanks to these modules that the system can ensure a high speed of inquiry processing, adapt to changing loads, and integrate with the company's logistics infrastructure.

4. The fourth group consists of logistics units and operational modules of the company, which are responsible for order fulfillment, inventory management, transportation, and other key processes. Data received from the ICSSLS regarding client inquiries, complaints, and forecasted needs are used by these units to optimize routes, plan resources, and increase operational efficiency.

5. The system's participants can also include partners and third-party service providers, who provide additional services such as transport outsourcing, IT support, or integration with external e-commerce platforms. Their participation allows for expanding the system's capabilities, increasing its flexibility, and creating additional value for clients.

6. Finally, the system's analytical and cognitive modules play an important role, implementing machine learning and artificial intelligence algorithms. They analyze accumulated data, forecast inquiries and problems, form recommendations for operators and automated modules, and ensure continuous system learning to increase service effectiveness.

Structurally, the ICSSLS covers several interconnected levels: informational, analytical, operational, cognitive, and collaborative (Fig. 2).

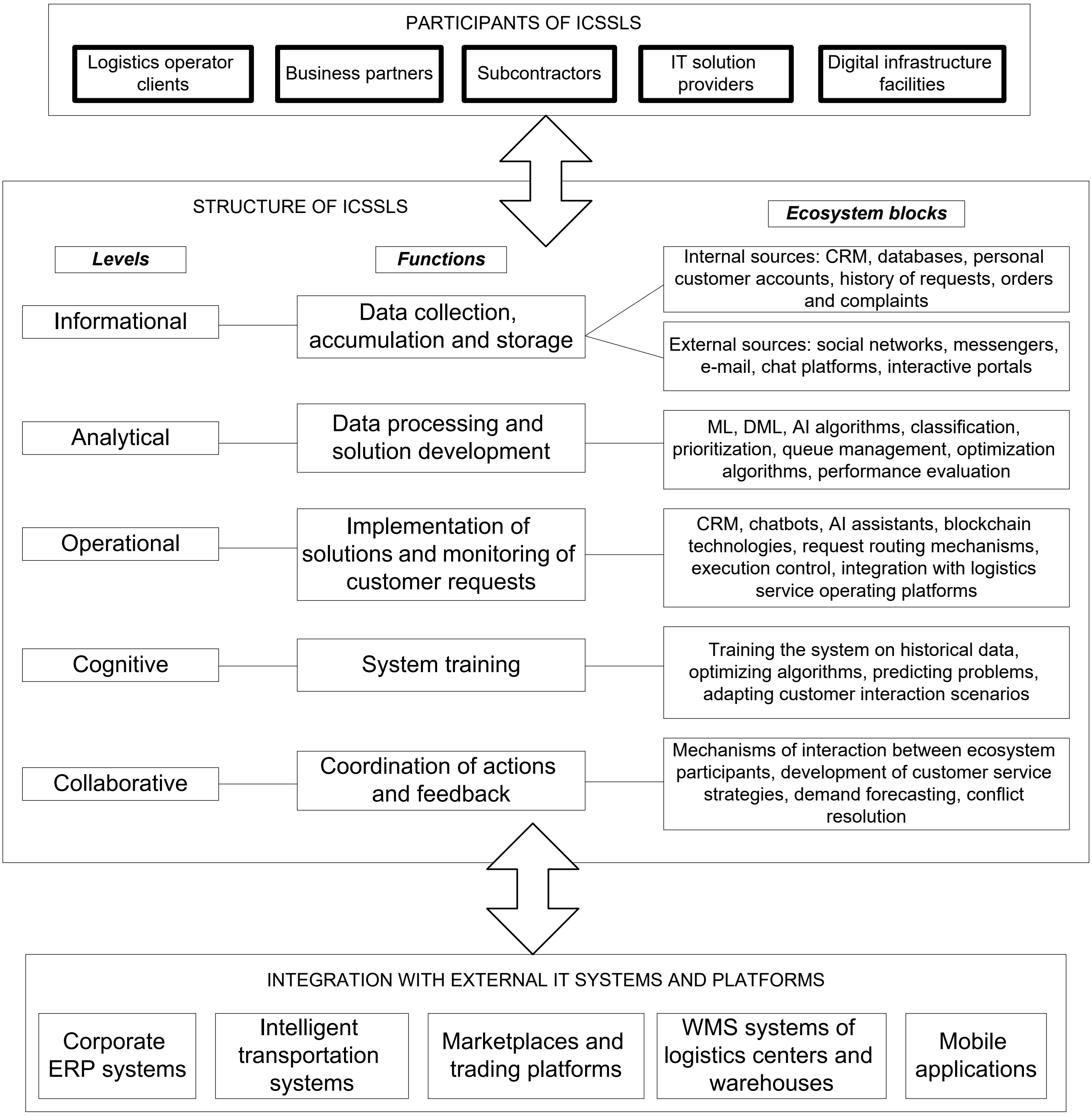

Figure 2 – Conceptual model of intelligent customer support system of logistics services (ICSSLS)

Source: authors' development

At the informational level, data on clients, their inquiries, requests, and complaints are collected and centralized, along with information from external sources such as social media, messengers, email, chat platforms, and interactive portals. This level forms the basis for analytical processing and decision-making.

At the analytical level, information is systematized and processed using artificial intelligence and machine learning algorithms. Natural language processing (NLP) algorithms are used for classifying and recognizing inquiries, machine learning models (ML, DML) for forecasting potential problems and determining the most effective scenarios for client interaction, as well as systems for evaluating performance indicators of inquiry processing. This level allows the system to adapt to the dynamic nature of inquiries and ensures data-driven decision-making.

The results of the analytical processing are passed to the operational level, where the practical implementation of solutions takes place: automated chatbots and CRM systems process inquiries, route them to the appropriate units, control the execution of requests in real-time, and ensure interactive client interaction. This level provides a quick response to client needs and continuous support for logistics service operations.

The cognitive level is responsible for training the system on historical data and optimizing client interaction scenarios. Thanks to the use of artificial intelligence algorithms, the system can forecast problems, offer recommendations for operators and automated processes, and increase the efficiency of inquiry processing based on accumulated experience.

At the collaborative level, coordination among the company's support, logistics, and management departments is carried out, and rules for feedback and internal procedures for optimizing service processes are formed. This level ensures the integration of the ICSSLS into the overall structure of the logistics company and contributes to its strategic adaptation to changing market needs.

An intelligent customer support system of logistics services does not function in isolation but is integrated into a wide network of digital services that ensures the effective management of information flows and interaction among various elements of the logistics ecosystem. A primary area of interaction is data exchange with CRM systems, which store the history of client interactions, allowing the ICSSLS to receive up-to-date information on orders, previous inquiries, and individual client needs. This ensures service personalization and increases the speed of response to inquiries.

Interaction with ERP systems is also important, as they are responsible for managing company resources, inventory planning, order processing, and coordinating logistics processes. The data received from the ICSSLS allows ERP modules to adjust delivery routes, forecast resource needs, and optimize supply chain management. In turn, ERP systems provide the ICSSLS with real-time information on product availability, delivery times, and order status, which increases the accuracy and effectiveness of customer service.

The ICSSLS also integrates with Transport Management Systems (TMS) and cargo tracking systems, which allows for real-time monitoring of cargo movement and provides clients with up-to-date order statuses. This ensures process transparency, reduces problem-response time, and increases client trust. Furthermore, the system interacts with e-commerce platforms, where a significant portion of client inquiries are generated. This integration allows for the automatic processing of orders, tracking of complaints and inquiries, and the analysis of user behavior to enhance service personalization. No less important is the interaction with analytical platforms and artificial intelligence modules, which provide for the processing of large volumes of data, problem forecasting, and the creation of recommendations for ICSSLS operators and automated modules. Thanks to this integration, the system is constantly learning, improving service effectiveness and optimizing logistics processes. Thus, the ICSSLS acts as an integration hub among various digital services of the company, ensuring bidirectional data exchange, process automation, forecasting, and service personalization. This interaction allows for the creation of a unified, coordinated digital ecosystem where logistics efficiency, responsiveness to client needs, and the strategic value of service are all enhanced.

To measure the effectiveness of ICSSLS implementation, we can propose metrics that are a key tool for evaluating service quality and the operational performance of the ecosystem. They not only allow for a quantitative determination of the level of customer satisfaction but also for an assessment of the effectiveness of internal processes, the identification of bottlenecks, and the well-founded adoption of management decisions regarding service optimization.

These metrics include:

1. CSAT (Customer Satisfaction Score) is a metric of customer satisfaction with a service or a specific interaction. The metric is measured using short post-service surveys where clients rate their experience on a scale, for example, from 1 to 5 or from 1 to 10. A high CSAT indicates effective support, fast inquiry processing, and high-quality customer interaction. For the ICSSLS, this metric allows for an assessment of how well the system, including its automated modules and operators, meets user expectations.

2. CSI (Customer Satisfaction Index) is a metric that measures the level of consumer satisfaction across various aspects of a company's operations. This includes an analysis of product quality, service level, pricing policy, staff competence, and service efficiency. To determine the CSI, surveys are typically conducted where clients express their impressions of their interaction with the company through a series of specific questions. From an ICSSLS perspective, the data obtained from the CSI can be analyzed to form a final index that reflects overall customer satisfaction.

3. NPS (Net Promoter Score) measures clients' willingness to recommend a company or its logistics service to others. The metric is calculated based on clients' answers to the question: "How likely are you to recommend our company?" on a scale from 0 to 10. Clients are divided into Promoters (9-10), Passives (7-8), and Detractors (0-6). NPS allows for the evaluation of long-term client loyalty and service effectiveness in terms of creating a positive customer experience. In the context of the ICSSLS, NPS reflects the support system's impact on the logistics company's reputation and clients' willingness to use its services again.

4. SLA (Service Level Agreement) defines the level of service a company guarantees to its clients, in the form of specific parameters: response time to an inquiry, order processing time, and the percentage of problems resolved within a specified period. Monitoring the SLA allows for an evaluation of the ICSSLS's performance, the compliance of processes with established standards, and the effectiveness of automated algorithms in providing service. Non-compliance with the SLA can indicate weak points in the system or insufficient integration with logistics processes.

5. IQS (Internal Quality Score) is an internal quality metric that relates to Key Performance Indicators (KPIs) and measures the effectiveness of employees or teams to evaluate service quality and achieve set goals. In a business context, IQS helps to assess how well employees perform their tasks, ensuring a high level of customer service quality. It can include indicators such as the quality of responses to inquiries, the speed of response to client requests, their satisfaction, and other aspects of client interaction. However, unlike the previous metrics, the evaluation is from the perspective of the employees themselves. This metric is used to monitor and improve the work of employees within the ICSSLS, helping to understand where there are opportunities for process optimization.

6. CES (Customer Effort Score) measures how easy it was for clients to interact with the company to resolve their needs or problems. The metric is calculated based on clients' answers to the question: "How difficult was it to resolve your problem?" on a scale from 1 to 7, where 1 means "very easy" and 7 means "very difficult." A low CES score indicates ease of interaction and, as a rule, a higher level of satisfaction and loyalty, while a high score indicates that clients have to make significant efforts, which can lead to client churn. CES focuses on how convenient it was for clients to find information, resolve a problem, or make a purchase. Research has shown that reducing the effort a client puts into solving their problem has a stronger effect on loyalty than attempts to "delight" the client. This metric is relevant for any interaction within the ICSSLS.

7. Automation Level. This metric reflects the proportion of support processes that are

performed automatically, without operator involvement. The automation level is evaluated as a percentage of the total number of inquiries or processes that are handled by the system independently, for example, by chatbots, forecasting algorithms, or automatic inquiry routing scenarios. A high automation level allows for reducing the workload on operators, shortening inquiry processing time, and increasing the accuracy of standard procedures. At the same time, it is important to ensure a balance between automation and human control in cases of complex or non-standard inquiries.

In combination, these metrics allow for evaluating service quality, client loyalty, the effectiveness of service standard fulfillment, and the degree of process automation, all of which are critically important for assessing the operational effectiveness of the ICSSLS and its integration into the logistics ecosystem. The use of these metrics ensures systematic control over the functioning of the ICSSLS, promotes increased customer-centricity, resource optimization, and forms the basis for the strategic development of logistics companies in a competitive environment.

Implementing an intelligent customer support system of logistics services provides numerous advantages for both the company and the end-users. First, the integration of intelligent technologies enhances the speed and accuracy of client inquiry processing. Automated processes that use artificial intelligence and machine learning algorithms can significantly reduce response time, optimize the routing of requests, and provide personalized service tailored to the individual needs of each user.

Second, the ICSSLS contributes to increasing the transparency of logistics processes. Clients receive up-to-date information on delivery status, product availability, and potential risks, which builds trust in the service and reduces the number of repeated inquiries. Third, the system enables the accumulation and analysis of data, which allows logistics companies to forecast demand, identify problem areas in delivery processes, and optimize inventory management.

In addition, the ICSSLS creates feedback mechanisms that ensure the cyclical learning of the system and the adaptation of logistics processes to changing market conditions. This increases the efficiency of the entire logistics network, as data-driven decisions help to reduce costs, improve delivery accuracy, and enhance interaction among all participants in the supply chain.

A key advantage of implementing the ICSSLS is the creation of synergy between customer satisfaction and the efficiency of logistics operations. Clear, fast, and personalized support increases user loyalty, while the optimization of internal processes helps to reduce operational costs and increase company productivity. Thus, the integration of an intelligent customer support system allows for the comprehensive optimization of logistics services, increases a company's market competitiveness, and creates a stable foundation for the development of an intelligent logistics ecosystem.

In modern logistics practice, examples of forming customer support ecosystems can be seen in the experience of leading international companies. Amazon, for instance, has built its own service ecosystem based on a combination of e-commerce, logistics capabilities, and high-tech customer support. Its key feature is the integration of digital platforms with tracking and delivery management systems, as well as the use of artificial intelligence for service personalization and fast response to client inquiries. In turn, DHL has created a comprehensive logistics ecosystem that combines transport, warehousing, and information services with an extensive network of customer support centers. The system is based on the principles of omnichannel, where a client can access the service through mobile applications, online platforms, or contact centers, while digital tools ensure transparency and flexibility in interaction. An example of successful customer support integration into a logistics ecosystem is also UPS, which actively applies digital technologies to automate service, tracking, and supply forecasting. Its ecosystem covers not only logistics processes but also a developed infrastructure of service centers and virtual assistants, which ensures a high speed of inquiry processing and forms a sustainable customer-centric service model. Thus, Amazon, DHL, and UPS demonstrate different approaches to building customer support ecosystems, but all are based on a combination of innovative technologies, integrated platforms, and a focus on client needs (Table 2).

Therefore, Amazon Logistics demonstrates the most complete integration of digital platforms, a high level of automation, and advanced analytics, making it a global benchmark for the ICSSLS. DHL and UPS also have strong systems for integration and automation, but compared to Amazon, they are less personalized and less focused on large-scale analysis of customer behavior. In general, giants like Amazon, DHL, UPS, or DB Schenker have already formed their own intelligent customer support ecosystems, which combine a high level of digitalization, automation, and customer-centricity. Their practices include the integration of multi-channel communications, the use of artificial intelligence to forecast customer needs, service personalization, and big data analytics to increase operational efficiency.

In Ukraine, where the logistics services market is in a phase of active transformation and adaptation to digital challenges, the implementation of similar approaches is strategically important. Using international experience will help to accelerate the formation of intelligent customer support systems, avoid common mistakes, and immediately aim for the highest service standards. This will increase the level of consumer trust, boost the competitiveness of Ukrainian companies, and facilitate their integration into global supply chains.

Table 2 – Comparative analysis of logistics service customer support ecosystems

Characteristics	Amazon Logistics	DHL	UPS
Digital Platform Integration	Full integration of CRM, ERP, TMS, AI analytics	Integration with client ERP/CRM, digital platforms	Integration of mobile applications, web portal and CRM
Process Automation	AI chatbots, routing, sorting centers, robotic warehouses	Automated sorting centers, real-time cargo tracking	AI chatbots, route optimization, partial sorting automation
Transparency and KPIs	Clear SLAs, CSAT, CSI and NPS monitoring, blockchain technologies, real-time reports	SLA, delivery tracking, blockchain technologies, KPIs for business customers	SLA, CSAT, CSI and NPS monitoring, blockchain technologies, reporting for corporate clients
Customer Focus	Personalized services, demand forecasting, fast feedback	Information services, status notifications, integration with business processes	Personalized services, operational support via mobile application and web portal
Analytics and Improvement	AI for delay forecasting, route optimization, big data analysis	Routing analytics, logistics problem prediction	Using data to optimize logistics and customer service
Level of Automation	High (about 70–80% of routine processes automated)	High in sorting and tracking	Medium–high, automation of routine operations and routing

In Ukraine, there are already logistics companies that are actively adopting and adapting international experience to national realities, forming their own intelligent customer support systems. For example, Nova Poshta demonstrates a high level of digitalization, developing mobile applications, chatbots, and real-time shipment tracking services that align with the practices of global leaders. Delivery focuses on optimizing service processes for business clients, implementing digital tools for managing logistics services and automated customer support. The company Zammler, focused on international transportation and complex logistics, applies modern approaches to supply chain management, introducing elements of integrated information systems to increase transparency and efficiency. Ukrposhta, as a national operator, is modernizing its infrastructure and digital services, expanding the possibilities of electronic communication with clients and implementing the automation of key processes.

A comparison of Ukrainian logistics companies with the benchmark global ICSSLS systems (Amazon, DHL, UPS) can be made using key criteria of effectiveness and technological level, as presented in Table 3.

Table 3 – Comparative analysis of the use of intelligent customer support systems by international and Ukrainian companies

Features	International companies (on the example of Amazon, DHL, UPS and DB Schenker)	Ukrainian companies (on the example of Nova Poshta and Delivery)
Digital Platform Integration	Full integration of CRM, ERP, TMS, AI-analytics. Real-time data access allows you to predict problems and automatically route cargo.	CRM and ERP integration mainly for business clients, mobile applications and chatbots for B2C. AI analytics integration is limited, real-time data automation is developing.
Process Automation	High level of automation of warehouse processes, sorting and routing; AI processes a significant part of customer requests	Automated sorting centers (especially at Nova Poshta), chatbots and request routing scenarios. The level of automation is lower, approximately 40–60% of routine processes.
Transparency and KPIs	Clear SLAs, regular monitoring of CSAT, CSI, NPS, blockchain technologies, big data analytics for predicting problems.	Open KPIs, SLAs in Nova Poshta and Delivery, CSAT, CSI and NPS are being gradually implemented, analytics are mostly internal.
Customer Focus	Personalization of service, recommendation algorithms, fast feedback.	Main focus on delivery speed and service availability; personalization is still limited (notifications, push notifications, branch evaluation).
Analytics and Improvement	AI for predicting delays, optimizing routes, analyzing customer behavior.	Analytics mainly for logistics optimization and resource planning, AI is used in limited scenarios (chatbots, basic forecasting).

Therefore, Ukrainian companies, such as Nova Poshta and Delivery, show significant progress in implementing digital services and automation, especially in cargo tracking and client communication. However, in terms of the level of AI analytics integration, service personalization, and full process automation, they still lag behind global benchmarks (Amazon, DHL, and UPS).

In general, we can say that the formation of an intelligent customer support system of logistics services is a strategic direction for the development of modern logistics companies. Its implementation will not only make it possible to optimize operational processes, but also create long-term benefits, strengthening customer loyalty and the position of companies in the market.

Conclusions. The study found that the evolution of customer support systems in logistics from traditional call centers to intelligent ecosystems reflects the general trends of digitalization, increasing demands for customer-centricity, and the growing complexity of logistics processes. The key stages in the development of service models were analyzed, and it was determined that modern logistics operators are increasingly integrating intelligent technologies, particularly artificial intelligence, Big Data, automation, and predictive analytics, to enhance the speed, accuracy, and personalization of customer service. The research confirmed the importance of an ecosystem approach, which allows for comprehensive interaction among supply chain participants and the creation of additional value for clients.

Intelligent customer support systems of logistics services (ICSSLS) continue to develop rapidly in response to growing market demands, the digitalization of business processes, and heightened customer expectations for service speed and quality. The prospects for the development of such systems are primarily related to the deeper integration of artificial intelligence and machine learning, which allows for automatically processing larger volumes of inquiries, forecasting problems, and creating personalized solutions for each user. The application of AI analytics opens up new opportunities for optimizing delivery routes, planning resources, monitoring service metrics and managing customer loyalty.

A conceptual model of an intelligent customer support system of logistics services (ICSSLS) was developed, which considers the multi-level structure of interaction among digital platforms, service modules, and ecosystem participants.

Methodological approaches for evaluating the effectiveness of such systems were determined using modern metrics, including CSAT, CSI, NPS, SLA, IQS, CES and the level of automation. A practical analysis of case studies of leading international companies (Amazon, DHL, UPS) and Ukrainian operators (Nova Poshta, Delivery) showed that the implementation of intelligent customer support ecosystems contributes to improved service quality, cost optimization, and stronger competitive positions in the market.

Overall, the results of the study prove that the intellectualization of customer support is a strategic direction for the development of modern logistics ecosystems. It not only ensures a business's adaptation to new market conditions but also creates long-term advantages by combining technological innovation with a focus on customer needs.

The strategic development of the ICSSLS involves a deeper integration with the company's digital ecosystem, including CRM, ERP, TMS, and analytical platforms. This allows for the creation of a single information space where all data on clients, orders, and logistics processes are interconnected and available in real time. This integration ensures not only increased efficiency in inquiry processing but also the forecasting of peak loads, reduced delivery times, and decreased operational costs.

An important component of strategic development is increasing the level of automation, which includes not only processing routine inquiries through chatbots and routing scenarios but also the automatic creation of recommendations for operators in complex or non-standard situations. This helps to achieve a balance between the efficiency of automated processes and human control in critical cases, increasing the accuracy and quality of service.

Additionally, a promising direction is the use of Big Data analytics to assess customer behavior, forecast demand, and develop new service offerings. Such data can be applied to create personalized proposals, adapt pricing plans, optimize delivery routes, and increase the level of customer satisfaction and loyalty.

The key driver of ICSSLS development is artificial intelligence, as it provides automation, personalization, forecasting, analytics, and continuous system improvement. Its application allows for increased service effectiveness, reduced inquiry processing time, lower costs, and the creation of a competitive advantage in the logistics services market. In the long term, AI integration becomes a strategic element of the digital transformation of logistics companies.

At a strategic level, the development of the ICSSLS also involves an orientation toward interacting with partners and integrating into global logistics ecosystems. This allows for expanding the service's geographical reach, increasing the speed of order processing, and ensuring the transparency of logistics processes at all stages of delivery.

In conclusion, the prospects and strategic development of the ICSSLS are focused on the maximum integration of digital platforms, an increased level of automation, the application of AI analytics, and service personalization, which allows companies to create highly effective, adaptive, and customer-oriented logistics ecosystems. In the long term, this forms a competitive advantage, reduces costs, increases service speed and accuracy, and strengthens a company's reputation in the market.

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Dolynskyi S.V. PhD in Economics, Associated Professor, Carpathian Institute of Entrepreneurship, Open International University of Human Development «UKRAINE» (Khust, Ukraine)

ORCID – 0000-0002-6565-1264
Researcher ID –
Scopus author id: – 57214468472
E-Mail: dolynskyi74@gmail.com

Dabizha V.V. PhD in Public administration, Associate Professor, Associate Professor of the Department of International Relations and Political Consulting, Open International University of Human Development «UKRAINE» (Kyiv, Ukraine)

ORCID – 0000-0002-7000-4635
Researcher ID –
Scopus author id: – 57218620866
E-Mail: verynchik@ukr.net

Kostina T.Yu. Senior Lecturer of the Department of Economics and Management, Carpathian Institute of Entrepreneurship Open International University of Human Development «UKRAINE» (Khust, Ukraine)

ORCID – 0009-0009-9586-252X
Researcher ID –
Scopus author id: –
E-Mail: kostinatatka@i.ua

POLITICAL AND COMMUNICATION MANAGEMENT IN THE SYSTEM OF ENSURING THE COMPETITIVENESS OF MODERN ENTERPRISES

Serhii Dolynskyi, Vira Dabizha, Tetiana Kostina. "Political and communication management in the system of ensuring the competitiveness of modern enterprises". *The article presents a comprehensive analysis of the role of political and communication management as key factors in ensuring the competitiveness of modern enterprises.*

Particular attention is paid to the main functions of political management, including analytical, adaptive, integrative, protective, and lobbying functions, which enable enterprises to effectively assess the political situation, forecast its impact on business operations, adapt strategies to changes in the regulatory and legislative environment, establish partnerships with state, supranational, and public institutions, and minimize risks associated with political instability.

Furthermore, the main areas of communication management are examined, including internal communications that support corporate culture and employee motivation, external communications aimed at interaction with clients, partners, investors, and society, reputation management that builds a positive image and trust in the company, and crisis communication that ensures conflict management and minimizes negative consequences.

Based on the conducted analysis, the synergistic effects of integrating political and communication management are identified, which manifest in enhanced strategic stability of the enterprise, strengthened reputational capital, improved communication efficiency, and risk management, all of which contribute to increased market competitiveness.

It is also emphasized that in Ukraine, communication management remains underdeveloped and often implemented in a spontaneous manner, highlighting the need to develop a specialized methodology for its systematic implementation and effective use as a tool for enhancing enterprise competitiveness.

***Keywords**:* political management, communication management, enterprise competitiveness, strategic stability, corporate culture, communications, enterprise adaptation, external environment

Сергій Долинський, Віра Дабіжа, Тетяна Костіна. «Політичний та комунікаційний менеджмент у системі забезпечення конкурентоспроможності сучасних підприємств». *Стаття присвячена комплексному аналізу ролі політичного та комунікаційного менеджменту як ключових чинників забезпечення конкурентоспроможності сучасних підприємств.*

Особлива увага приділена вивченню основних функцій політичного менеджменту, серед яких аналітична, адаптаційна, інтеграційна, захисна та лобістська, що дозволяють підприємствам ефективно оцінювати політичну ситуацію, прогнозувати її вплив на діяльність бізнесу, адаптувати стратегії до змін регуляторного та законодавчого середовища, встановлювати партнерські відносини з державними, наддержавними та громадськими інституціями, а також мінімізувати ризики, пов'язані з політичною нестабільністю.

Крім того, проаналізовано напрями комунікаційного менеджменту, до яких належать внутрішні комунікації, що підтримують корпоративну культуру та мотивацію персоналу, зовнішні комунікації, спрямовані на взаємодію з клієнтами, партнерами, інвесторами та суспільством, репутаційний менеджмент, який формує позитивний імідж та довіру до компанії, а також кризові комунікації, що забезпечують управління конфліктними ситуаціями та мінімізацію негативних наслідків.

На основі проведеного аналізу визначено синергетичні ефекти інтеграції політичного та комунікаційного менеджменту, які проявляються у підвищенні стратегічної стійкості підприємства, зміцненні репутаційного капіталу, підвищенні комунікаційної ефективності та управлінні ризиками, що в сукупності сприяє зростанню конкурентних позицій на ринку.

Підкреслено, що в Україні політичний та комунікаційний менеджмент залишається недостатньо розвиненим і часто застосовується стихійно, що визначає потребу в розробці спеціальної методології для його системного впровадження та ефективного використання як інструменту підвищення конкурентоспроможності підприємств.

Ключові слова: політичний менеджмент, комунікаційний менеджмент, конкурентоспроможність підприємства, стратегічна стійкість, корпоративна культура, комунікації, адаптація підприємства, зовнішнє середовище

Introduction. In today's world of globalization and constant market transformation, companies are forced to seek new approaches to ensuring their competitiveness. Business efficiency increasingly depends not only on internal resources and development strategies, but also on the ability of enterprises to interact with political institutions and establish high-quality communications with various stakeholders. Therefore, the combination of political and communication management as key components of corporate governance is becoming particularly relevant.

Political management in the context of business activities covers the processes of interaction between business and government bodies, regulatory structures, international organizations, and professional associations. It creates conditions for businesses to adapt to changes in the political environment, minimizes risks, and allows them to take advantage of new opportunities arising from political decisions.

Communication management, in turn, is aimed at building effective communications both within the organization and in interaction with external audiences. It ensures the formation of a positive image of the enterprise, support for corporate culture, reputation capital management, and the creation of long-term partnerships with customers and society.

The scientific problem lies in the fact that political and communication management are most often considered separately, although it is their integration that creates synergy, which directly affects the competitiveness of modern enterprises.

Analysis of recent research and publications. O. Aharkov, V. Bebyk, V. Shcherbak provide comprehensive insights into the theoretical foundations and practical application of political management. Their works emphasize the role of political actors, institutions, and processes in shaping strategic decision-making, which can be adapted for business environments.

The majority of the sources O. Hudz, I. Makovetska, N. Zhyhailo focus on communication management, covering internal and external communication, reputation management, and crisis communication. These studies highlight the crucial role of communication in sustaining corporate culture, building stakeholder trust, and ensuring effective interaction with the external environment.

K. Pichyk, V. Khrapkina, O. Lepokhin provide broader perspectives on management theory, with sections dedicated to communication processes. Their works support the integration of communication and political dimensions into a wider strategic framework of enterprise management.

The formulation of the goals of the article is research on political and communication management in the system of ensuring the competitiveness of enterprises, as well as the identification of effective mechanisms for combining them in corporate governance practice.

Presentation of the main results. Political management is the interaction of business with government agencies, regulatory bodies, international organizations, and professional associations. Political management helps create conditions for a company to adapt to changes in the political environment, minimizing risks and taking advantage of new opportunities that arise as a result of political decisions. As for communication management, its activities are more focused on building effective communications both within the organization and in interaction with external audiences. Communication management ensures the formation of a positive image of the enterprise, support for corporate culture, reputation capital management, and the creation of long-term partnerships with customers and society.

In the context of enterprise operations, political management may be conceptualized as a structured system of methods, instruments, and mechanisms designed to facilitate effective interaction between businesses and state as well as supranational institutions, political entities, and civil society organizations. Its primary objective is to anticipate and mitigate political risks, account for the influence of legislative and regulatory frameworks, and develop adaptive strategies that enable enterprises to remain resilient and competitive within a dynamic external environment [10].

The core functions of political management at the enterprise level are summarized in Table 1.

Table 1 – Main functions of political management in an enterprise

Function	Content
Analytical	Assessment of the political situation and forecasting its impact on business.
Adaptive	Adjustment of the enterprise strategy to changes in the regulatory environment.
Integrative	Establishment of partnerships with political and civil society institutions.
Protective	Minimization of risks related to political crises, instability, or changes in legislation.
Lobbying	Representation of business interests at different levels of government and in professional associations.

Source: developed by author

Thus, political management serves as an important tool for ensuring the stability of an enterprise, as it enables proactive action by shaping not only the internal strategy but also the external operating environment.

Communication management is a set of methods, principles, tools, and forms of influence accumulated in global practice, used by communicators to affect recipients in order to enhance the efficiency of information flow interactions among employees, specific groups, or organizations in the communication process aimed at solving strategic and tactical tasks [8].

When revealing the core essence of communication management as a factor in improving the efficiency of managing economic systems, it is essential to emphasize its dual nature [9].

On the one hand, communication management constitutes a component of the theory of managing economic systems. It studies the interaction and interconnection, in time and space, of the elements that form and effectively utilize all types of capital of economic systems, while also identifying the patterns of exchanging information, knowledge, and intellectual property in the process of forming and developing an economic system. On the other hand, communication management is considered as an independent professional activity of the producer, intermediary, and consumer (subjects and objects of the economic system) in the implementation of a communication strategy, developed in accordance with the motives, attitudes, interests, relationships, and specific objectives of each participant [9].

Let us consider the key role of communication management. We have defined communication management as an integral component of corporate governance that ensures effective information exchange between the enterprise and its stakeholders. Its essence lies in the planning, organization, and implementation of communication processes aimed at achieving the strategic objectives of the business [7].

The key directions of communication management include:

– internal communications, which support corporate culture, employee motivation, and the coordination of staff actions;

– external communications, focused on interaction with customers, partners, suppliers, investors, and society;

– reputation management, which shapes the company's positive image and builds trust;

– crisis communications, which enable the enterprise to maintain stability and minimize negative consequences in cases of conflict situations [5].

The main directions of communication management in enterprises are presented in Table 2.

Table 2 – Main areas of communication management in a company

Direction	Content
Internal Communication	Supporting corporate culture, employee motivation, and coordination of staff actions.
External Communication	Interaction with customers, partners, suppliers, investors, and society.
Reputation Management	Building a positive corporate image and trust.
Crisis Communication	Managing conflict situations, maintaining stability, and minimizing negative consequences.

Source: developed by author

Communication management directly affects the competitiveness of an enterprise, since in today's information society the value of a brand and reputational capital are becoming important intangible assets. An enterprise that communicates effectively with its target audiences has a much greater chance of maintaining competitive positions even under challenging economic conditions [2].

We have summarized in Table 3 the process of synergistic effects arising from the combination of political and communication management (strategic resilience, reputational advantages, adaptability).

Table 3 – Synergistic effects of combining political and communication management of an enterprise

Area of Influence	Synergy Result
Strategic Resilience	Ability of the enterprise to effectively adapt to political changes and regulatory challenges
Reputational Advantages	Building stakeholder trust and enhancing corporate legitimacy
Communication Efficiency	Ensuring transparent dialogue with authorities, partners, and the public
Risk Management	Reducing negative consequences of crisis situations through political and communication integration
Competitiveness	Strengthening market position through harmonization of political and communication strategies

Source: developed by author

The systematization presented in Table 3 demonstrates that the combination of political and communication management creates additional competitive advantages for the enterprise. In particular, strategic resilience is achieved through the ability of businesses to promptly adapt to changes in the political environment and legislation. Reputational advantages are reflected in the strengthening of trust among key stakeholders, which enhances the legitimacy of the enterprise in the market. Communication efficiency is manifested in establishing open and transparent dialogue with governmental bodies, partners, and society. Risk management is also a crucial factor, as the integration of political and communication strategies minimizes the consequences of crisis situations. Altogether, these effects increase the competitiveness of the enterprise, ensuring its stable development under the changing conditions of a globalized economy [6].

Therefore, the analysis of the functions of political management, the directions of communication management, and the synergistic effects of their combination indicates that these managerial components are complementary elements in the system of ensuring enterprise competitiveness. Political management enables businesses to adapt to changes in the external environment, establish effective interaction with governmental and civil institutions, and minimize risks associated with political instability. Communication management, in turn, ensures the creation of a positive image, the development of corporate culture, and effective interaction with key stakeholders. Their integration generates an additional synergistic effect, which is manifested in strengthening reputation, increasing strategic resilience, and enhancing the competitive positions of enterprises in the market [3].

In Ukraine, communication management remains a relatively underexplored phenomenon. In many cases, communication processes are managed spontaneously, guided by inspiration rather than systematic approaches. Ukrainian enterprises have not yet fully harnessed the potential that communication can offer. Unfortunately, communication has not received sufficient attention as a factor of enterprise competitiveness. Issues related to communication management at both the enterprise and regional levels remain insufficiently studied. These aspects highlight the necessity of developing a specialized theoretical approach to communication management [1, 4].

Conclusions. The conducted analysis demonstrates that political and communication management are complementary components of enterprise governance, both of which significantly influence strategic stability and competitiveness in a globalized environment. Political management ensures adaptation to external political and regulatory changes, enables risk minimization, and strengthens relationships with state and supranational institutions. Communication management, in turn, facilitates effective interaction with internal and external stakeholders, supports corporate culture, enhances reputation, and provides resilience during crisis situations.

The integration of political and communication management generates a clear synergistic effect. Enterprises that combine both approaches gain strategic sustainability, improved legitimacy, enhanced reputational capital, and the ability to build transparent dialogue with partners, authorities, and society. This synergy ultimately increases competitiveness, allowing companies to maintain stable development even under conditions of political and economic uncertainty.

At the same time, in the Ukrainian context, communication management remains relatively underdeveloped and often occurs spontaneously rather than systematically. Enterprises have yet to fully recognize its role as a driver of competitiveness. This indicates the urgent need to develop a comprehensive theoretical and methodological approach to communication management, which would allow businesses to leverage its potential more effectively. Strengthening this direction, along with the integration of political and communication strategies, will contribute to the sustainable growth of Ukrainian enterprises and their successful positioning in the international arena.

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Voloshchuk N.Yu. PhD in Economics, Associate Professor of the Department of Economics and Management Carpathian Institute of Enterprising Open International University of Human Development «UKRAINE» (Khust, Ukraine)

ORCID – 0000-0002-0783-0205
Researcher ID –
Scopus author id: –
E-Mail: nadezdavoloshka@gmail.com

Shcherban M.D. PhD in Economics, Associate Professor of the Department of Economics and Management Carpathian Institute of Enterprising Open International University of Human Development «UKRAINE» (Khust, Ukraine)

ORCID – 0009-0007-8322-6775
Researcher ID –
Scopus author id: –
E-Mail: scherban1492@gmail.com

Voitenko H.V. PhD in Economics, Associated Professor, Carpathian Institute of Entrepreneurship, Open International University of Human Development «UKRAINE» (Khust, Ukraine)

ORCID – 0009-0005-9100-2574
Researcher ID –
Scopus author id: –
E-Mail: Bilovarci@ukr.net

SEGMENTATION OF THE FINANCIAL MARKET AND ITS EFFICIENCY IN THE MODERN ECONOMY

Nadiia Voloshchuk, Mariia Shcherban, Halyna Voitenko. "Segmentation of the financial market and its efficiency in the modern economy ". *The article is devoted to a comprehensive analysis of financial market segmentation and assessment of its effectiveness in the modern economy.*

It is determined that the financial market provides for the exchange of financial assets, the formation of capital prices, the accumulation of temporarily free funds and their return to circulation, which contributes to the efficient allocation of resources. The main segments of the financial market are considered – the currency, money, capital, derivatives, and precious metals markets – along with their specific functions, interaction, and role in mobilizing capital, managing risks, and stimulating investment activity.

The mechanisms of state and economic regulation aimed at ensuring the stability of the financial system, market transparency, protection of investors' rights, and development of innovation are analyzed. The results of *the study confirm that the effective functioning of financial market segments creates conditions for sustainable economic development, support for entrepreneurship, and investment activity.*

The article is of practical importance for improving financial market regulation policy and forming capital mobilization strategies.

***Keywords**:* financial market, market segmentation, operational efficiency, financial market regulation, capital, investments, financial assets, economic development, state regulation

Надія Волощук, Марія Щербан, Галина Войтенко. «Сегментація фінансового ринку та ефективність його функціонування у сучасній економіці». *Стаття присвячена комплексному аналізу сегментації фінансового ринку та оцінці ефективності його функціонування у сучасній економіці.*

Визначено, що фінансовий ринок забезпечує обмін фінансовими активами, формування цін на капітал, акумуляцію тимчасово вільних коштів та їх повернення в оборот, що сприяє ефективному розподілу ресурсів. Розглянуто основні сегменти фінансового ринку – валютний, грошовий, ринок капіталу, ринок похідних фінансових інструментів та ринок дорогоцінних металів та їх специфічні функції, взаємодію та роль у мобілізації капіталу, управлінні ризиками та стимулюванні інвестиційної активності.

Проаналізовано механізми державного та економічного регулювання, спрямовані на забезпечення стабільності фінансової системи, прозорості ринку, захист прав інвесторів та розвиток інновацій. Результати дослідження підтверджують, що ефективне функціонування сегментів фінансового ринку створює умови для сталого економічного розвитку, підтримки підприємництва та інвестиційної діяльності.

Стаття має практичне значення для вдосконалення політики регулювання фінансових ринків та формування стратегій мобілізації капіталу.

Ключові слова: фінансовий ринок, сегментація ринку, ефективність функціонування, регулювання фінансового ринку, капітал, інвестиції, фінансові активи, економічний розвиток, державне регулювання.

Introduction. The financial market is a key instrument of the modern economy, ensuring the circulation of financial assets, the mobilization of capital, and the stimulation of investment activity. It consists of several interrelated segments: currency, money, capital market, derivatives market, and precious metals market, which perform specific functions but form a single system.

The effective functioning of the financial market segments ensures economic stability, optimal resource allocation, and promotes entrepreneurship and innovation. Market regulation, both legal and economic, aims to create a transparent and secure environment for all participants, protect the interests of investors, and stimulate innovation.

This article is devoted to the study of the main segments of the financial market, their interaction and effectiveness, as well as the study of regulatory mechanisms that ensure the stability of the financial system and promote economic development.

Analysis of recent research and publications. Recent research on financial markets highlights their pivotal role in ensuring economic stability, efficient allocation of capital, and stimulation of investment activity. Financial markets are increasingly recognized not merely as platforms for trading assets, but as complex systems composed of multiple interrelated segments, including the currency market, money market, capital market, derivatives market, and precious metals market. Each segment performs distinct functions while simultaneously interacting with others, contributing to the overall efficiency and resilience of the economic system. The main scientists studying the researched issues are N. Antonyuk, S. Arutyunyan, L. Alekseienko, S. Dmytrov, I. Krupka, V. Khodakivska, I. Semencha, O. Svitlychna, I. Shkolnyk.

Overall, current research consistently demonstrates that a detailed understanding of financial market segmentation, regulation, and efficiency is crucial for designing policies that ensure the optimal mobilization of capital, the protection of investor interests, and the sustainable development of the national and global economy.

The formulation of the goals of the article is to study the segmentation of the financial market and assess the efficiency of its functioning in the modern economy, analyze the role of key segments in capital mobilization, management of financial assets, and stimulation of investment activity, as well as determine the importance of state and economic regulatory mechanisms in ensuring the stability, transparency, and development of the financial system.

Presentation of the main results. The financial market is an important component of the financial system, where financial assets such as cash, securities, and other financial instruments are exchanged. The financial sector is a platform for the meeting of capital supply and demand, where market participants such as investors, banks, households, companies, and government institutions carry out transactions involving the purchase, sale, exchange, and management of financial resources.

Various transactions take place in the financial market, including investing in securities, opening bank accounts, concluding loan agreements, and raising capital. In addition, it plays a key role in asset pricing, determining the value of cash, and regulating risk levels. The financial market reflects the state of the economy and the financial stability of the country, and also influences the level of investment activity, consumer spending, and the development of entrepreneurship [9]. In a broad sense, it performs one of the key functions the return of capital to circulation.

The current financial market is not just a place for buying and selling assets, but a multifaceted sphere that combines a number of sub-market groups that have become integral parts of its existence. These sub-groups perform important functions and interact with each other, forming a coherent system that ensures the effective functioning of the economy. The main subgroups of the financial market include [4]:

1. The currency market is a specific area of the financial market where currencies are exchanged. It plays an important role in the global economy, providing the opportunity for conversion and various currency exchange transactions. Participants in the currency market include: central banks, which act as regulators in the currency market and manage the country's currency reserves; commercial banks, which provide access to currency transactions for their clients; financial institutions specializing in currency transactions, such as stock exchanges and brokerage firms; and individual investors who engage in currency exchange transactions for investment purposes or to hedge against currency risk.

2. Money market – a market for short-term financial assets where transactions with bills of exchange, certificates of deposit, and other instruments are carried out [3]. The money market plays a key role in the functioning of the financial system by providing liquidity and stability. It is a platform for short-term financial transactions such as short-term lending, liquidity management, and money transfers. Participants in the money market include central banks, commercial banks, corporations, investment funds, financial institutions, and individual investors. They use the money market to conduct transactions with short-term financial instruments in order to earn interest, preserve capital, and manage risk.

3. Capital market – a segment of the financial market where companies and governments can raise long-term financial resources by issuing and selling securities such as stocks and bonds [3]. It plays a key role in the functioning of the economy, promoting entrepreneurship, investment, and innovation. The capital market comprises two main segments: the stock market and the bond market. The stock market allows companies to raise capital by issuing shares and selling them to investors. The bond market, on the other hand, provides the opportunity to issue and sell bonds to raise debt capital for a specific term at a specific interest rate. Capital market participants include corporations, investment funds, banks, insurance companies, pension funds, and individual investors. They use this market to raise capital for various projects, such as business expansion, research, equipment and technology purchases, as well as for risk management and future financial security.

4. The derivatives market is a segment of the financial market where participants enter into agreements to buy or sell financial contracts. This market allows them to hedge against price volatility risks, speculate on price changes, and invest using financial derivatives [2]. The main types of derivative financial instruments include options, which give the right to buy or sell an asset at a certain price during a certain period; futures, which are contracts to buy or sell an asset at a certain price in the future; and swaps, which are agreements to exchange cash flows or financial assets between participants. Participants in the derivatives market include investment funds, banks, insurance companies, corporations, and individual investors. They use derivatives primarily to hedge against price risks, profit from price fluctuations, and diversify their investment portfolios.

5. The precious metals market is a segment of the financial market where various types of metals that are highly valuable and widely used are traded. Among the most well-known precious metals are gold, silver, platinum, and palladium. Participants in the precious metals market include producers, consumers, investors, and traders. They use this market for various purposes, including capital preservation, inflation protection, investment portfolio diversification, and the use of metals in manufacturing and industry [1].

In economics, financial processes are organized through the mechanism of the financial market and the financial services market (Fig. 1), and the main components of financial market regulation are presented in Fig. 2.

The process of financial market regulation is the economic influence on the system of relationships operating in the financial market with the aim of improving, organizing, ensuring, and protecting the interests of all market participants.

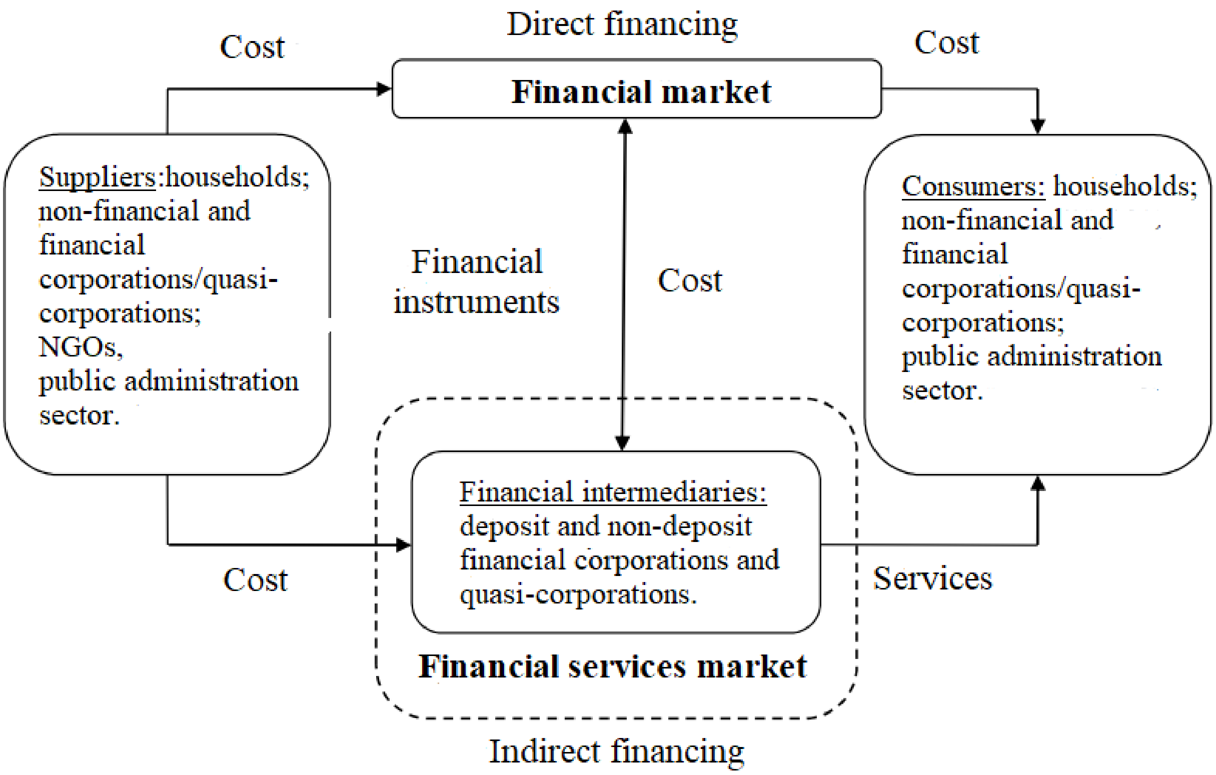

Figure 1 – Organization of financial processes in the economy through the mechanism of the financial market and the financial services market

Source: base on [5].

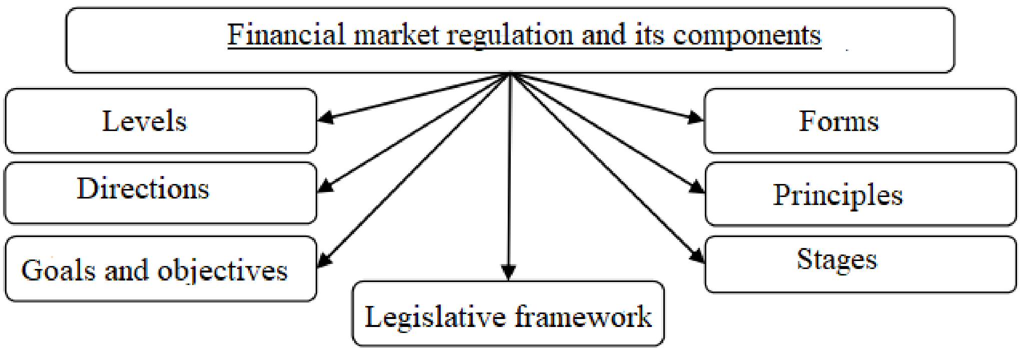

Figure 2 – Components of financial market regulation

Source: base on [5].

Scholar S.M. Esh defines that: "the main goal of financial market regulation is to ensure the harmonization of all types of interests of market participants: individual, corporate, state, as well as the interests of intergovernmental and international associations" [6]. Among these, the following are highlighted:

– promoting order in the market and normal conditions for the functioning of all its participants;

– "ensuring the security of the financial system" [6];

– developing uniform requirements for all market participants;

– ensuring (free, open) pricing processes for financial instruments (demand, supply) on the market;

– creating an effective market with financial incentives (rewards) for business;

– creating new markets (market innovations);

– the ability to achieve public goals (social, distributive);

– introducing a system to protect investors' interests (abuse);

– regulating the number of monopolies and the level of monopoly;

– maintaining transparency and openness of the financial market, protection from self-destruction.

In the economic environment, a "system of financial market regulation principles" has been developed by direction, level, and form specifically for a particular market segment: money, currency, securities, credit, financial services, etc [7].

The main principles of the financial market regulation system are:

– protection of the legitimate rights and interests of investors by the state;

– disclosure by issuers of information necessary for investors to make decisions;

– equal access to information for market participants;

– reflection of the relationship between supply and demand through prices for financial assets;

– support for fair competition between market participants;

– the existence of a state regulatory body with stable, clearly defined powers;

– promotion of innovation in the securities industry, etc.

The main areas of regulation of the financial market and its segments:

– regulation of the composition of market instruments and the scope of their rights;

– regulation of transactions and forms of trading in financial assets;

– regulation of information flows in the market;

– regulation of the composition of market participants and certain types of their activities [10].

State regulation is aimed at implementing a comprehensive system of measures, namely control, regulation, supervision of market processes and participants, prevention of abuse and violations of established rules within the national financial market.

State regulation of the financial market is aimed at the procedure for issuing and circulating financial assets; regulating such types of financial activities as trading in financial assets, currency values, providing credit and insurance services, issuing activities, etc.; regulating the activities of specific financial institutions (commercial banks, insurance companies, investment companies, pension funds, and other intermediaries) and foreign market participants [13].

Let us consider the forms of financial market regulation – direct (legal) and indirect (economic) regulation. Indirect (economic) regulation is based on economic levers aimed at shaping various external conditions (setting prices, fluctuations in supply and demand, shaping a competitive environment) [11].

Direct regulation is a comprehensive system of processes for establishing rules of conduct for participants in the financial market to ensure their application and resolution of disputes in the course of activities, and to hold those who violate these rules (norms) accountable. The legal regulation system includes two areas [8].

The main actors in the financial market are the state, households (the population), financial institutions, foreign organizations, etc [12].

Financial market objects include financial assets, financial market instruments (agreements, contracts), modern financial technologies (plastic cards, payment systems, software, etc.) – temporarily available funds (money) can be invested in them [12].

The financial market is a key link in the transfer of funds. In essence, it creates opportunities for the transfer of capital, thereby enabling the economy to exist. Its spheres and markets provide diverse opportunities for capital investment, thereby accumulating significant amounts of funds to be returned to circulation. This mechanism allows for the effective distribution of resources, directing them to where they are most needed and where they can be used with maximum return. Thanks to the financial market, investments are attracted to various sectors of the economy, stimulating their development and promoting innovation.

Conclusions. The financial market is a key component of the financial system and an important mechanism for the functioning of the economy. It provides for the exchange of financial assets, forms capital prices, promotes the efficient allocation of resources, and accumulates temporarily free funds for their return to circulation. The main segments of the financial market are the currency, money, capital, derivatives, and precious metals markets, which perform specific functions but interact with each other to form a single system.

Regulation of the financial market, both in legal and economic terms, is aimed at ensuring the stability, transparency, and security of the financial system, protecting the interests of participants, and stimulating investment activity. Essentially, the financial market creates conditions for mobilizing capital, maintaining liquidity, and developing entrepreneurship, which, in turn, contributes to the country's economic growth and innovative development.

Thus, the modern financial market is not only a platform for buying and selling financial assets, but also a complex instrument of economic policy and investment development that harmonizes the interests of the state, business, and the population, creating the conditions for sustainable economic development.

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