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ЕКОЛОГІЧНА МОДЕРНІЗАЦІЯ МІЖНАРОДНОЇ ЛОГІСТИКИ ЯК ЧИННИК РОЗВИТКУ ПІДПРИЄМНИЦТВА В УМОВАХ ГЛОБАЛЬНИХ ТРАНСФОРМАЦІЙ

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ECOLOGICAL MODERNIZATION OF INTERNATIONAL LOGISTICS AS A FACTOR IN THE DEVELOPMENT OF ENTREPRENEURSHIP UNDER CONDITIONS OF GLOBAL TRANSFORMATIONS

Анотація. *У статті досліджено теоретичні засади, світовий досвід і практичні перспективи екологічної модернізації міжнародної логістики як важливого чинника розвитку підприємництва в умовах глобальних трансформацій та післякризового*

відновлення економіки. Обґрунтовано, що сучасна логістика відіграє ключову роль у формуванні сталих ланцюгів постачання, а її екологізація стає необхідною умовою підвищення конкурентоспроможності бізнесу та інтеграції національних економік у світовий ринок. Проаналізовано вплив транспортної діяльності на довкілля, зокрема структуру викидів парникових газів за видами транспорту, та визначено основні напрями скорочення негативного екологічного впливу логістичних процесів. Узагальнено міжнародний досвід упровадження «зелених» логістичних рішень, зокрема використання екологічних стандартів ISO, цифрових технологій, декарбонізації транспорту, розвитку енергоефективної інфраструктури та прозорої нефінансової звітності. Доведено, що екологічна модернізація логістики не лише сприяє зменшенню викидів і раціональному використанню ресурсів, а й формує нові можливості для підприємницької діяльності, зокрема для малого та середнього бізнесу, інноваційних стартапів і цифрових логістичних платформ. Особливу увагу приділено можливостям адаптації європейських екологічних підходів до умов України в контексті євроінтеграційних процесів. Визначено ключові напрями розвитку екологічно орієнтованої логістики в Україні, серед яких модернізація транспортної інфраструктури, цифровізація логістичних процесів, розвиток «зелених» логістичних центрів і стимулювання інвестицій у низьковуглецеві технології. Зроблено висновок, що екологічна модернізація міжнародної логістики може стати ефективним інструментом довгострокового підприємницького зростання, структурної трансформації економіки та підвищення її стійкості в умовах глобальних викликів.

Ключові слова: *міжнародна логістика, екологічна модернізація, сталий розвиток, «зелена» логістика, підприємництво, декарбонізація, цифровізація, логістична інфраструктура, євроінтеграція, індустріальні парки,економічне відновлення.*

Abstract. *The article explores the theoretical foundations, global experience, and practical prospects of the ecological modernization of international logistics as a key factor in entrepreneurship development amid global transformations and post-crisis economic recovery. It substantiates that modern logistics plays a crucial role in forming sustainable supply chains, while its greening is becoming a necessary condition for enhancing business competitiveness and integrating national economies into the global market.*

The environmental impact of transport activities is analyzed, particularly the structure of greenhouse gas emissions by transport modes, and the main directions for reducing the negative environmental effects of logistics processes are identified. The study summarizes international experience in implementing green logistics solutions, including the application of ISO environmental standards, digital technologies, transport decarbonization, the development of energy-efficient infrastructure, and transparent non-financial reporting. It is proven that ecological modernization of logistics not only contributes to emission reductions and rational resource use, but also creates new opportunities for entrepreneurial activity, especially for small and medium-sized enterprises, innovative start-ups, and digital logistics platforms.

Special attention is given to the adaptation of European environmental approaches to Ukraine's conditions in the context of European integration. Key priorities for the development of environmentally oriented logistics in Ukraine are outlined, including modernization of transport infrastructure, digitalization of logistics processes, development of green logistics centers, and stimulation of investments in low-carbon technologies. The article concludes that ecological modernization of international logistics can become an effective tool for long-term entrepreneurial growth, structural economic transformation, and strengthening economic resilience to global challenges.

Keywords: *international logistics, ecological modernization, sustainable development, "green" logistics, entrepreneurship, decarbonization, digitalization, logistics infrastructure, European integration, Industrial parks, economic recovery.*

L26,F23,Q56

Problem statement. In modern conditions of globalization and growing environmental awareness of mankind, the issue of ecological modernization of logistics processes acquires special significance. Active international trade, an increase in transport volumes and the intensive development of customs-brokerage services have led to a significant environmental burden on the environment. Traditional models of logistics, oriented exclusively on economic efficiency, require transformation in the direction of sustainable development. Ecological modernization — is a complex system of changes in technological, management and regulatory approaches, aimed at reducing the negative impact of human activity on the environment while maintaining the competitiveness of business. For the sphere of international logistics and customs mediation, it means a transition to more environmentally safe forms of transportation, energy-efficient technologies, digitalization of cargo clearance processes and the introduction of environmental management systems.

The relevance of the study lies in the need to combine the economic interests of the state and business with environmental requirements dictated by international agreements and internal standards. Ukraine, integrating into the global economic space, faces the need to reform its logistics and customs system in accordance with the principles of sustainable development. This problem acquires special weight in the context of the implementation of the Association Agreement with the EU, the transition to the European Green Deal, the implementation of new environmental regulators (in particular CBAM), digitalization of customs procedures and harmonization of national legislation with European environmental requirements.

Analysis of recent research and publications. The theoretical basis of the study is the scientific works of domestic and foreign scientists in the field of sustainable development, international logistics, environmental management and development of entrepreneurship, as well as regulatory and legal documents of the European Union and Ukraine.

In the world scientific literature, the problematic of ecological modernization of logistics and the formation of the concept of «green logistics» is thoroughly disclosed in the works of Alan McKinnon, M. Christopher, J.-P. Rodrigue, J. Rogerson, P. Dekker, Y. Sheffi, who study the issues of optimization of transport flows, eco-modernization of supply chains, reduction of carbon emissions, as well as the impact of logistics innovations on business competitiveness in the conditions of globalization.

A significant contribution to the development of theoretical foundations of sustainable entrepreneurship and environmentally oriented business models was made by M. Porter, M. Kramer, J. Elkington, who substantiate the relationship between environmental responsibility, innovation and long-term economic efficiency of enterprises.

Among Ukrainian scientists, a significant contribution to the study of problems of environmental management, sustainable development and greening of entrepreneurial activity was made by T. Melnyk, L. Deineko, I. Sotnyk, O. Shmandii, V. Dykan, who focus on the adaptation of international environmental standards to national conditions and the role of logistics in ensuring economic recovery. Issues of the development of logistics systems and transport infrastructure in the context of European integration of Ukraine are reflected in the works of N. Chukhrai, Ye. Krykavskyi, O. Kuzmin.

Regulatory and institutional aspects of the greening of international trade and logistics are covered in the reports of the European Commission, OECD, UNEP, World Bank and World Customs Organization (WCO), which form the methodological basis for the implementation of «green» logistics practices at the international level.

At the same time, comprehensive scientific studies combining ecological modernization of international logistics with the development of entrepreneurship in the conditions of global transformations and economic recovery of Ukraine remain insufficiently presented in the domestic scientific literature, which determines the relevance and scientific significance of the chosen topic.

Research methodology. The methodological basis of the study is a set of general scientific and special methods of cognition that provide a comprehensive analysis of ecological modernization of international logistics as a factor in the development of entrepreneurship in the conditions of global transformations. In the work, methods of analysis and synthesis are applied — to reveal the essence of ecological logistics, generalize theoretical approaches and systematize scientific views; comparison method — for comparing national and international practices of implementing «green» logistics solutions; methods of statistical generalization and grouping — for assessing the dynamics of logistics indicators, environmental effects and entrepreneurial activity.

Systemic and structural-functional approaches were used to study the relationship between logistics processes, environmental requirements and the development of entrepreneurial structures in international supply chains. Methods of economic analysis and elements of economic modeling were applied with the aim of assessing the impact of ecological modernization of logistics on the costs of enterprises, their competitiveness and innovative potential.

To identify global trends and best practices, content analysis of international strategic and program documents in the field of sustainable development and «green» logistics was used, as well as the method of benchmarking of leading international logistics companies and entrepreneurial structures.

Comparative legal analysis was applied to study environmental regulatory approaches and standards in different countries and to assess the possibilities of their adaptation to the conditions of Ukraine. The complex use of the indicated methods allowed to substantiate the directions of ecological modernization of international logistics as a tool for stimulating entrepreneurship, increasing business resilience and forming a competitive economy in the conditions of global transformations.

Highlighting previously unresolved parts of the general problem. Special attention needs to be paid to the analysis of modern trends of «green» logistics, evaluation of the possibilities of adaptation of international practices to national conditions and substantiation of the prospects for the introduction of environmentally oriented logistics solutions in Ukraine with the aim of increasing the competitiveness of entrepreneurial structures, stimulating innovative activity and ensuring sustainable economic development.

At the same time, there are a number of problems that hold back full-fledged ecological modernization of the customs and logistics sphere. First, the insufficient level of legislative regulation of environmental aspects in the field of logistics. Ukrainian legislation currently contains only general provisions on environmental protection, however, special norms are missing that determine the requirements for the environmental friendliness of transport operations, logistics warehouses or customs clearance of goods. Second, the low level of state funding for environmental programs in the transport and logistics sector does not allow for rapid modernization of infrastructure.

Special attention is required for the transformation of logistics chains specifically for industrial enterprises that are in a state of economic recovery. For them, ecological modernization of logistics is not only a requirement of the EU, but also a possibility to reduce

the cost of production through energy efficiency, which is critical for survival in deficit conditions.

Article goals consist in a comprehensive study of the essence, theoretical foundations and world experience of ecological modernization of international logistics, as well as in determining its role as a factor in the development of entrepreneurship in the conditions of global economic, technological and environmental transformations.

Main material presentation. Within the framework of the concept of sustainable development, three main groups of principles are distinguished — economic, environmental and social. Economic principles are aimed at ensuring the stability and efficiency of the activity of enterprises. They include rational use of resources, innovativeness and development of competitiveness through the introduction of new technologies. Environmental principles provide for the preservation of the natural environment by reducing harmful emissions, minimizing energy consumption and implementing environmental management. Social principles are oriented towards creating safe and fair working conditions, developing corporate culture and increasing the well-being of society [1].

In the sphere of international logistics, the principles of sustainable development are reflected in practical tools, in particular standards and initiatives of the world level. One of the most important is the implementation of ISO series standards — in particular ISO 14001 [2], which regulates the environmental management system, and ISO 26000, which defines the foundations of social responsibility. These standards help companies integrate the principles of sustainability into the management of logistics processes, making them more efficient and transparent.

An important role is played by international environmental agreements and initiatives that affect the functioning of logistics systems. Among them are the Paris Climate Agreement, the European Green Deal, the UN program «Sustainable Development Goals — 2030», as well as the initiatives of the International Maritime Organization (IMO) regarding the reduction of emissions in the transport sector.

In practice, the implementation of the principles of sustainable development in logistics manifests itself through a number of specific directions. First, it is the development of transport technologies with a low level of emissions — electric, hybrid and hydrogen transport. Second, the use of alternative energy sources at logistics facilities, in particular solar and wind stations. Third, the transition to digital management systems that allow to optimize routes, reduce empty runs and decrease fuel costs.

The implementation of the principles of sustainable development in the international logistics system involves not only technological and infrastructural modernization, but also the improvement of institutional mechanisms for regulating the movement of commodity flows. Effective functioning of logistics in the conditions of global transformations is impossible without transparent, predictable and environmentally oriented procedures for crossing the state border, which directly affect the costs, time parameters and competitiveness of entrepreneurial activity.

International logistics is an important component of the development of entrepreneurial activity and foreign economic relations, as it ensures efficient movement of commodity flows across the state border, coordination of transport, warehouse and regulatory procedures, as well as continuity of supply in global value added chains. The level of development of logistics systems directly affects the competitiveness of enterprises, their ability to enter foreign markets and adapt to changes in the international business environment.

In modern conditions, international logistics is increasingly combining with entrepreneurship through the introduction of innovative business models, digital platforms and service solutions aimed at optimizing logistics processes. The environmental dimension of the logistics activity of enterprises acquires special significance, since the rational organization of transportation, optimization of routes and reduction of transport idle time contribute to a decrease in costs, a reduction in emissions and the formation of environmentally responsible entrepreneurial practice [3].

In the conditions of economic recovery of Ukraine, international logistics acts as a key factor in activating entrepreneurial activity, developing exports and restoring production and marketing links. Modernization of logistics infrastructure, development of «green» logistics solutions and harmonization of regulatory procedures with European standards create a favorable environment for small and medium-sized businesses, stimulate innovative entrepreneurship and the attraction of investments. Thus, the combination of the development of international logistics, environmental responsibility and entrepreneurial initiative forms the basis for stable economic growth and post-war recovery of Ukraine [3].

World experience of ecological modernization of logistics demonstrates that countries with developed economies pay significant attention to reducing the negative impact of transport activity on the environment. Responsible attitude to resources, development of environmentally clean technologies and digitalization of customs procedures become an integral part of economic policy. The concept of «green» logistics in most countries of the world is considered as a tool for achieving sustainable development, since it combines efficient management of material flows with environmental safety.

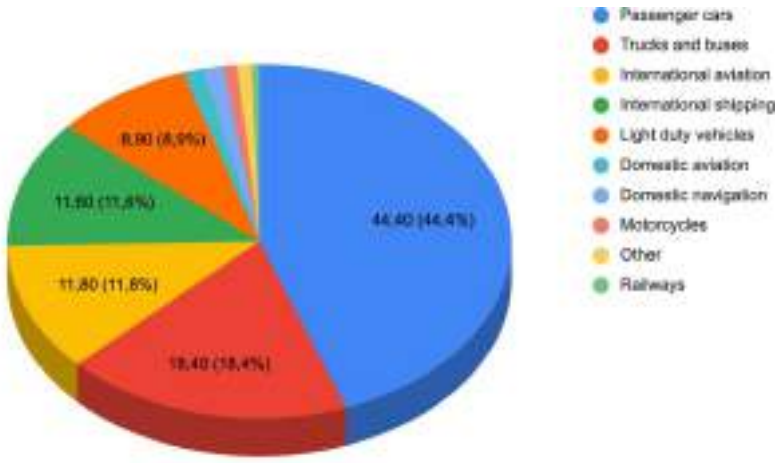

Figure 1. Structure of harmful emissions by different types of transport [4]

Throughout the world, transport is one of the main sources of atmospheric pollution. The transport sector in the world accounts for approximately 20 % of total CO_2 (carbon dioxide) emissions [4]. Every car, burning 1 kg of gasoline, uses 15 kg of air, in particular 5.5 kg of oxygen. When burning 1 t of fuel, 200 kg of carbon monoxide is emitted into the atmosphere. Approximately 55% of the total volume of harmful substances is accounted for by road transport, which includes over 200 different compounds. In such a

context, no company that provides logistics services or has a connection with them can ignore the problem of atmospheric pollution by harmful emissions from various types of transport [5, p.63]. Figure 1 reflects the structure of CO_2 emissions in the world transport sector by type of transport.

Overall, the emission structure demonstrates the need to reorient transport policy to lower-carbon modes of transport and implement «green» logistics solutions. «Green logistics» — is a logistics that is not only environmental, but also often socially friendly and economically efficient, so it contributes to the formation of logistically environmental and economically efficient systems [6, p.111].

The first to implement «green» logistics were the countries of the European Union. In the European Union, the transport sector is the largest source of greenhouse gas emissions among all sectors. In 2024, it is estimated that transport emissions grew by +0.7 % compared to 2023 [7]. European policy in this sphere is based on the principles of the European Green Deal, which defines a strategic goal — achieving climate neutrality by 2050. Key directions of the European Green Deal (EGD) are clean energy, climate action, construction and renovation, sustainable industry, sustainable mobility, reducing environmental pollution, biodiversity, sustainable agricultural policy (Farm to Fork Strategy) [8].

For EU logistics companies, strict requirements have been introduced regarding the reduction of CO_2 emissions, increasing energy efficiency and optimizing transport routes. The European model of «green» logistics also provides for the active use of multimodal transportation, when one delivery chain combines several modes of transport — sea, rail, road and air. This allows to choose the most optimal routes from the point of view of ecology and cost. For example, transportation of goods by rail contributes to the reduction of greenhouse gas emissions several times compared to road transport. The European Commission supports this direction through the «Connecting Europe Facility» (CEF) program, which finances the creation of «green» transport corridors and environmentally safe logistics hubs [9].

In the United States of America, the development of «green» logistics occurs under the influence of market mechanisms and corporate initiatives. American companies actively invest in the introduction of alternative energy sources, electric transport, intelligent route management systems and warehouse automation. The federal SmartWay Transport Partnership program, launched by the U.S. Environmental Protection Agency (EPA), stimulates logistics companies to reduce fuel consumption, improve the technical condition of transport and reduce harmful emissions. Program participants receive environmental certificates that increase their reputation and competitiveness in the market [10].

In Asia, the leading countries in the field of «green» logistics are Japan, South Korea and China. In Japan, environmental logistics policy is developed within the national «Eco-Ship» program, aimed at creating a low-carbon transport system. Japanese logistics companies use hybrid transport technologies, energy-saving warehouses with autonomous solar panels, as well as automated emission control systems. Special attention is paid to digital platforms that ensure tracking of the «carbon footprint» of each cargo in real time. In China, the issue of greening logistics has become a state priority within the policy of «green transformation of the economy». The country actively implementing the «Green Freight Initiative» program, which provides for modernization of the transport fleet, development of electric traction systems and increasing the energy efficiency of warehouse complexes.

In China, a system of «green tax incentives» has been introduced, which provides benefits to companies implementing environmental technologies. In addition, special economic zones with a low level of emissions have been created, where environmentally certified logistics enterprises are located.

The European Union is actively implementing environmental control in customs procedures through the integration of environmental criteria into the risk assessment system [8]. For example, cargoes with toxic substances or waste are subject to increased control, and companies that have «green» certification pass customs procedures in a simplified mode. Foreign approaches to «green» logistics and environmental customs administration have common features:

- orientation on digitalization of processes;
- stimulation of companies to environmental investments through tax benefits;
- strengthening of state environmental control;
- creation of international mechanisms for coordination and data exchange;
- formation of a culture of corporate environmental responsibility.

These elements constitute a universal model that can be adapted to the national conditions of various countries, in particular Ukraine. They prove that successful ecological modernization of logistics is possible only with the combination of technological innovations, political will and active participation of business. Such an approach ensures not only environmental safety, but also long-term economic sustainability in the global trade system.

The development of the concept of «green» logistics in the world is largely determined by the activities of leading international companies that implement environmentally oriented technologies and form new standards for supply chain management. Practical implementation of ecological modernization of international logistics as a factor in the development of entrepreneurship is presented in analytical-comparative Table 1.

Table 1

WORLD EXPERIENCE OF ECOLOGICAL MODERNIZATION OF INTERNATIONAL LOGISTICS AND ITS SIGNIFICANCE FOR DEVELOPMENT OF ENTREPRENEURSHIP IN UKRAINE

Company/ Country/ Region	Sustainability Strategy	Key Environmental Solutions	Achieved Effect	Value for Entrepreneurship	Relevance for Ukraine
DHL Group / Germany / Global [15]	GoGreen	Electric transport; biofuel; energy-efficient warehouses; solar panels; emission monitoring	Goal — zero CO_2 emissions by 2050	Increasing transparency and environmental responsibility of logistics services	High: can be adapted for the development of «green» logistics hubs and SMEs in Ukraine
Maersk / Denmark / Global [16,17]	Decarbonizing Logistics	Vessels on methanol and ammonia; AI-optimization of routes	Emission reduction by 70–80 %	Formation of stable maritime supply chains	High: relevant for modernization of port logistics and export

Company/ Country/ Region	Sustainability Strategy	Key Environmental Solutions	Achieved Effect	Value for Entrepreneurship	Relevance for Ukraine
Maersk + Unilever / Saudi Arabia [16, 17]	Partnership Green Logistics	Solar panels (64,000 m²); energy-efficient logistics park	≈ 5 % emission reduction	Development of corporate logistics alliances	Average: possible application in reconstruction of industrial and logistics parks
UPS / USA [12]	Sustainable Logistics	Electric and hybrid transport; system ORION	Saving >40 million l of fuel/year; – 100 thousand tons of CO_2	Digitalization of logistics and reduction of delivery costs	High: relevant for optimization of road transport and e-commerce
CMA CGM Group / France [14]	ACT with CMA CGM+	Vessels on LNG; emission compensation programs	–85 % NO_x (nitrogen oxides); –20 % CO_2	Greening of maritime business	High: promising for development of Black Sea logistics
Toyota Logistics Services / Japan [19]	Toyota Environmental Challenge 2050	Hybrid transport; automated warehouses; reuse of packaging	–50 % logistics waste	Integration of sustainability into production-logistics chains	Average: can be applied in industrial and agricultural logistics
Kuehne+Nagel / Finland / Global [11]	Net Zero Carbon	Sea Explorer; carbon footprint compensation	Route optimization by emission level	Providing environmentally oriented logistics services	High: useful for export-oriented business
Amazon / USA [13]	Climate Pledge	Electric trucks; LEED-warehouses; Shipment Zero	Goal — neutrality by 2040	Scaling «green» logistics in e-commerce	High: relevant for development of digital entrepreneurship
Carrefour / France [18]	Act for Food	Green distribution centers; short supply chains	Reduction of transport distances and CO_2	Support for local suppliers	High: relevant for agricultural entrepreneurship and regional logistics

Source: compiled by the authors on the basis of [11], [12], [13], [14], [15], [16], [17], [18], [19]

The analyzed world experience testifies that ecological modernization of international logistics acts as an effective tool for increasing the competitiveness of entrepreneurial structures. For Ukraine, the most relevant are practices related to digitalization of logistics, development of «green» transport, modernization of port and warehouse infrastructure, as well as formation of short and transparent supply chains, which is especially important in the conditions of economic recovery and European integration.

Comparative analysis of the experience of leading companies allows to single out several common trends that determine the modern approach to stable development of logistics in the world and key trends of stable development of international logistics, their content and significance for entrepreneurship (Table 2). Such an analysis well complements the previous comparative characteristic of companies and performs a synthetic (generalizing) function.

Table 2

KEY TRENDS OF SUSTAINABLE DEVELOPMENT OF INTERNATIONAL LOGISTICS IN THE ACTIVITIES OF LEADING COMPANIES

№	Trend	Content and implementation tools	Examples of companies	Value for entrepreneurship development
1	Digitalization of logistics processes	Use of analytical platforms, artificial intelligence, IoT for route optimization, energy consumption control and cost reduction	UPS (ORION), Maersk, Amazon, DHL	Reduction of logistics costs; increasing operational efficiency and business competitiveness
2	Decarbonization of transport	Transition to electric, hydrogen, LNG- and biofuel transport; renewal of vehicle fleets and fleets	DHL, UPS, Maersk, CMA CGM	Formation of environmentally responsible business models; compliance with international environmental requirements
3	Energy-efficient logistics infrastructure	Construction and modernization of warehouses and terminals according to LEED, BREEAM standards; use of RES	Amazon, DHL, Maersk + Unilever, Carrefour	Reduction of operational costs; increasing investment attractiveness of enterprises
4	Environmental transparency and reporting	Publication of ESG- and sustainability-reports; monitoring and accounting of emissions	Maersk, Kuehne+Nagel, DHL	Growth of investor and partner trust; access to «green» financing
5	Formation of corporate culture of sustainable development	Staff training; environmental motivation; internal «green» initiatives	Toyota Logistics Services, DHL, Carrefour	Increasing innovation potential and social responsibility of business

Source: compiled by authors based on [11], [12], [13], [14], [15], [16], [17], [18], [19]

The establishment of environmentally oriented logistics in Ukraine is a complex and simultaneously promising process that reflects transformational changes in the economy, integration into world markets and the desire to meet European standards of sustainable development.

The concept of «green» logistics in the Ukrainian economy began to be actively used after the signing of the Association Agreement between Ukraine and the European Union.

Today, the level of greening of logistics processes in Ukraine remains moderate. Most transport companies continue to use equipment with a high level of emissions, and ener-

gy-efficient technologies and alternative types of fuel are introduced only at individual enterprises. In the structure of transport transportation, road transport prevails, which is the largest source of harmful emissions, while the share of rail, river and sea transportation, which are more environmentally appropriate, remains low.

At the same time, a gradual development of initiatives from the side of business is observed. Some large logistics operators, like «Nova Poshta», «Delivery», «Meest Express», implement programs for energy saving and reduction of resource consumption. For example, «Nova Poshta» started the transition to electric vehicles [20], tests solar panels for powering logistics terminals [21] and moves to the use of reusable packaging. Such steps contribute to the formation of a corporate culture of environmental responsibility.

It is worth noting the unevenness of environmental development of regions. In large cities — Kyiv, Lviv, Dnipro, Odesa — a larger number of «green» initiatives is observed, while in small settlements and industrial zones environmental standards are often not met due to a lack of resources and control.

An important aspect is the absence of systemic monitoring of environmental indicators in logistics. Today in Ukraine, centralized statistics on emission volumes of the transport sector, the level of energy consumption of logistics enterprises or the number of environmentally certified warehouses are not kept. This complicates the assessment of the effectiveness of state policy and hinders the adoption of justified management decisions.

Despite the existing structural, infrastructural and institutional problems, Ukrainian logistics retains significant potential for environmental renewal, the realization of which can become an important factor in the revival of entrepreneurial activity and economic recovery of the country. The advantageous geographical position of Ukraine, its transit potential, as well as gradual integration into the European economic space create prerequisites for the formation of a modern, environmentally oriented logistics system.

Therefore, the direction of ecological modernization is irreversible. In the future, it is specifically those logistics companies and customs operators that move earlier to the use of «green» technologies that will have strategic advantages in the European economic space.

Ukraine's transition to environmentally stable logistics models is not only a requirement of the time, but also a strategic necessity dictated by European integration obligations and global trends in the sphere of sustainable development. In the context of the restoration of the industrial potential of Ukraine, industrial parks should become a strategic site for the introduction of «green logistics». Concentration of production capacities on one territory allows to realize the concept of eco-industrial symbioses, such as: creation of joint multimodal terminals, use of a single digital platform for management of parks, their waste and raw materials («Data-Driven» approach) and joint use of autonomous energy sources (solar stations on warehouses), which reduces the «carbon footprint» of the industrial product still at the stage of shipment. With the aim of systematizing the main directions of ecological modernization of the logistics system of Ukraine and generalizing the tools for their practical implementation, it is appropriate to provide a generalizing Table 3.

It reflects key directions for implementing the principles of sustainable development in logistics, corresponding mechanisms of state support and expected results for the development of entrepreneurial activity. Such an approach allows to clearly demonstrate the relationship between environmental transformation of logistics, increasing the efficiency of economic processes and the formation of competitive advantages of domestic enterprises in the international economic space.

Table 3

MAIN DIRECTIONS OF ECOLOGICAL MODERNIZATION OF LOGISTICS IN UKRAINE AND THEIR IMPACT ON DEVELOPMENT OF ENTREPRENEURSHIP

№	Direction of ecological modernization	Key measures and tools	Role of the state	Expected effect for entrepreneurship
1	Development of environmental transport infrastructure	Expansion of rail and river transportation; electrification of railways; modernization of rolling stock	State program «Green Transport Ukraine»; attraction of international investments and grants	Reduction of logistics costs; increasing business export potential
2	Digitalization of logistics processes	Electronic waybills; automation of document circulation; GPS, blockchain, data analytics	Creation of a national platform of electronic logistics	Reduction of delivery time; increasing efficiency and transparency of entrepreneurial operations
3	Development of «green» warehouses and logistics centers	Energy-efficient buildings; RES; waste sorting and water reuse systems	Tax benefits; grants for environmental projects	Reduction of operational costs; growth of investment attractiveness of business
4	Development of alternative fuel and electric transport	Electric trucks; charging infrastructure; LNG and biofuel	Compensations for equipment cost; soft lending	Formation of «green» logistics services; new market niches
5	Greening of customs-brokerage activity	Digital environmental control; database of environmentally dangerous goods; risk-oriented approach	Integration of IT-systems of customs and eco-agencies	Reduction of delays at the border; reduction of environmental risks for business
6	Certification and environmental rating	ISO 14001; voluntary status «Green Broker»	Introduction of a system of environmental preferences	Increasing the trust of international partners
7	Personnel training and environmental education	Educational programs on sustainable development and «green» logistics	Support for educational reforms and programs	Formation of qualified personnel potential
8	Innovative technologies (Smart Transport)	«IoT, Big Data, AI for flow management»	Pilot projects; international technical cooperation	Increasing logistics efficiency; innovative entrepreneurship
9	Tax and customs environmental policy	Benefits for «green» equipment; environmental fees	Reform of tax and customs system	Stimulation of environmentally responsible business
10	Eco-logistic integration of industrial parks	Creation of «green» logistics corridors between industrial clusters; joint charging of electric trucks	Benefits for residents of IP implementing eco-standards	Reduction of the share of logistics costs in the final price of industrial products; entry to EU markets without CBAM-duty

Source: [22, p.181, 182]

Thus, the generalization of the key directions of ecological modernization of the logistics system of Ukraine indicates that the introduction of principles of sustainable development is complex and requires coordinated actions of the state, business and international partners. The implementation of measures in the fields of development of «green» transport infrastructure, digitalization of logistics processes, greening of warehouse and customs-brokerage activity creates prerequisites for increasing the efficiency of the functioning of logistics chains and reducing their negative impact on the environment.

It is proven that for the industrial sector of Ukraine, ecological modernization of logistics should be considered not as a separate requirement, but as a component of the reindustrialization strategy. Implementation of a data-driven management model and development of eco-oriented industrial parks will allow domestic enterprises not just to restore production volumes, but to perform a «technological jump», integrating into global value added chains as environmentally responsible partners.

Simultaneously, environmental transformation of logistics acts as an important factor in activating entrepreneurial activity, since it opens new market niches, stimulates innovation and the attraction of investments, and also contributes to the integration of Ukrainian enterprises into international supply chains according to EU standards. Therefore, systemic introduction of «green» logistics solutions can be considered not only as a tool for environmental policy, but also as a strategic direction for economic recovery and stable development of Ukraine.

Discussion. The results obtained indicate that the logic of the economic behavior of enterprises in the field of international logistics in the conditions of global transformations differs significantly from its classical interpretation. Traditional approaches to logistics management are based on assumptions regarding the relative stability of supply chains, predictability of costs and rational choice of optimal routes and technologies. However, modern empirical studies convincingly demonstrate that under conditions of geopolitical instability, climate challenges and regulatory changes, these prerequisites are not met [4; 8]. In such a context, ecological modernization of logistics ceases to be exclusively a tool for minimizing negative impact on the environment and acquires the features of an adaptive economic strategy.

In scientific literature, two main approaches to the interpretation of greening logistics dominate. The first — technical-economic — focuses on cost optimization, emission reduction and increasing energy efficiency, often abstracting from entrepreneurial behavior [1; 7]. The second — institutional-regulatory — focuses on the impact of standards, environmental norms and policies, in particular the European Green Deal [2; 9]. The results of the study show that none of these approaches separately allows for explaining the transformation of logistics solutions during the period of global disturbances. The approach proposed in the article integrates these paradigms, considering ecological modernization as a result of the interaction of technological, institutional and entrepreneurial factors.

The issue of the economic appropriateness of «green» logistics solutions causes special debate. In a number of studies, it is emphasized that high investment costs and limited access to financing hold back their implementation, especially in countries with transitional economies [6]. Simultaneously, results of analysis of the activity of leading international companies (DHL, UPS, CMA CGM, Maersk) [12; 13; 15; 16; 18] demonstrate that ecological modernization forms long-term competitive advantages through lower operating costs, increasing the resilience of supply chains and strengthening reputa-

tional capital. This allows to interpret greening of logistics not as a cost factor, but as an investment in entrepreneurial resilience.

The proposed interpretation of the role of digitalization expands traditional approaches to «green» logistics. If in classical models digital technologies are considered primarily as a tool for increasing efficiency [14], then results of the study demonstrate their system-forming role in reducing the environmental burden and forming new business models. Practices of SmartWay [11] and GoGreen from DHL [16] confirm that digital solutions combine environmental monitoring with entrepreneurial analytics, changing the very logic of making logistics decisions.

Decarbonization of transport remains one of the most controversial directions of ecological modernization. Data from Our World in Data [4] and the European Environment Agency [8] testify to the critical contribution of the transport sector to CO_2 and NO_x emissions. Within this study, it is shown that the transition to low-carbon modes of transport has not only environmental, but also entrepreneurial consequences, stimulating the development of related markets — alternative fuel, electric transport, infrastructural and service solutions.

An important discussion aspect is the time dimension of ecological modernization. Most studies consider environmental solutions as one-time or project-based [3; 7], while results of this work point to their dynamic character. In the short-term perspective, «green» logistics solutions perform a compensatory function, while in the long-term perspective — they form new trajectories of entrepreneurial development. Such an approach correlates with modern concepts of the resilience of socio-economic systems [10], but offers a more detailed vision of the role of logistics in these processes.

Summarizing, the results of the study expand the instrumental possibilities of analysis of international logistics, combining concepts of sustainable development, entrepreneurship and technological transformation. Ecological modernization of logistics is interpreted not as a situational reaction to external challenges, but as a structured process subject to strategic management, measurement and adjustment. The proposed approach forms the basis for further research aimed at the quantitative assessment of the impact of «green» logistics solutions on entrepreneurial resilience and economic recovery in conditions of growing global turbulence.

Conclusions and prospects of further research. Thus, stable development in the field of logistics should be considered as a complex and multidimensional process that combines technological renewal, transformation of organizational approaches, realization of principles of social responsibility and establishment of efficient interaction between business and state institutions. Practice of leading international companies convincingly testifies that increasing the environmental efficiency of logistics systems not only does not limit economic efficiency, but also forms stable long-term advantages, in particular through productivity growth, strengthening customer trust and ensuring stability of development.

International experience of ecological modernization of logistics has significant applied meaning for Ukraine in the context of its gradual integration into global economic processes. Adaptation of progressive management and technological solutions will contribute to increasing the competitiveness of domestic logistics operators, approaching the national regulatory and legal framework to European environmental standards and modernization of customs-logistics infrastructure on the principles of sustainable development.

Introduction of environmentally oriented logistics solutions — in particular renewal of the transport fleet, development of energy-efficient warehouse infrastructure, digitalization of management of logistics processes and use of renewable energy sources — creates conditions for reducing operating costs and minimizing negative impact on the environment. This, in turn, strengthens the positions of Ukrainian enterprises on domestic and foreign markets, simplifies their inclusion into international supply chains and contributes to attracting investment resources.

In the context of European integration processes, coordination of national logistics practice with environmental requirements of the EU acquires special significance. Realization of «green» logistics approaches opens new prospects for development of small and medium entrepreneurship, formation of innovative services, digital platforms and startups oriented towards stable business models. Thus, ecological modernization of logistics emerges not only as a tool for reducing environmental risks, but also as an important driver for long-term entrepreneurial growth and structural renewal of the economy of Ukraine.

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