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PORT LOGISTICS OF UKRAINE AS A DRIVER OF SUSTAINABLE DEVELOPMENT IN THE BLACK SEA BLUE ECONOMY

ПОРТОВА ЛОГІСТИКА УКРАЇНИ ЯК ЧИННИК СТАЛОГО РОЗВИТКУ В УМОВАХ БЛАКИТНОЇ ЕКОНОМІКИ ЧОРНОГО МОРЯ

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This article examines the transformation of Ukraine's port logistics within the Black Sea Blue Economy and sustainable development framework. It shows the need to shift from a linear to a circular model to improve resource efficiency and reduce environmental impact. Climate change, supply chain restructuring, and wartime risks require modernization of seaports as key logistics hubs. The study highlights the role of renewable energy, digital platforms such as the Maritime Single Window, and smart logistics in reducing emissions and improving efficiency. Energy efficiency measures include shore power and renewable energy integration. Waste recycling infrastructure and circular economy principles are emphasized. Institutional coordination, ESG standards, and resilience are identified as key factors. The development of port logistics is essential for Ukraine's post-war recovery and integration into European networks.

Keywords: port logistics, blue economy, sustainable development, circular economy, maritime single window, port digitalization, Black Sea region.

Стаття присвячена дослідженню трансформації портової логістики України в контексті Блакитної економіки Черноморського регіону та парадигми сталого розвитку. Встановлено, що портова логістика України потребує переходу від традиційної лінійної моделі розвитку до циркулярної, що забезпечує більш ефективне використання ресурсів, зниження ресурсомісткості операцій та мінімізацію негативного впливу на довкілля. Обґрунтовано, що сучасні виклики, пов'язані з кліматичними змінами, перебудовою глобальних логістичних ланцюгів та воєнними ризиками, актуалізують необхідність комплексної модернізації морських портів як ключових елементів транспортно-логістичної системи України та Чорноморського регіону. Доведено, що інтеграція відновлюваних джерел енергії, цифрових платформ, зокрема системи Морського єдиного вікна, а також інтелектуальних логістичних технологій сприяє скороченню викидів парникових газів, підвищенню операційної ефективності та зміцненню стійкості портової інфраструктури. Особливу увагу приділено ролі енергоефективності як базового чинника сталого функціонування портів, зокрема через впровадження систем електропостачання суден від берега, використання сонячних та вітрових електростанцій на території портів та модернізацію енергетичної інфраструктури. Обґрунтовано необхідність створення спеціалізованих об'єктів портової приймальної інфраструктури для переробки відходів як вторинної сировини. Розроблено концепту-

альний підхід до інтеграції принципів блакитної та циркулярної економіки у портову логістику як єдину систему управління морськими ресурсами та потоками, що дозволяє поєднати економічну ефективність з екологічною стійкістю та підвищити адаптивність портової системи до зовнішніх викликів. Встановлено, що важливими умовами трансформації є також інституційна координація, впровадження ESG-стандартів та підвищення стійкості портової інфраструктури до зовнішніх шоків. Розвиток портової логістики України у рамках Блакитної економіки є важливим фактором післявоєнного відновлення та інтеграції у європейські транспортні мережі.

Ключові слова: портова логістика, блакитна економіка, сталий розвиток, циркулярна економіка, Морське єдине вікно, цифровізація портів, Чорноморський регіон.

Statement of the problem. The port sector of Ukraine today is not merely a component of the transport industry but a complex socio-economic system capable of becoming a key factor in the transformation of the Black Sea region within the framework of sustainable development. Under the conditions of a global climate crisis, the restructuring of global supply chains, and wartime challenges, Ukraine is forced to reconsider the role of seaports not only as cargo transshipment hubs but as integrated elements of the Blue Economy, where marine and coastal resources are utilized in accordance with ecological, technological, and economic principles.

Traditionally, ports have been perceived as centers of intensive cargo flows, where economic benefits prevail over environmental considerations. However, modern challenges require a fundamentally different approach based on sustainability, resource efficiency, and environmental responsibility. This determines the relevance of the study and the need to transform port logistics in line with the principles of the Blue Economy.

Analysis of recent research and publications. The concept of the Blue Economy has gained significant attention in recent years as a strategic framework for ensuring sustainable development of maritime regions. According to international reports, in particular the study by the United Nations Industrial Development Organization [1-2], ports are increasingly viewed as “blue ports”, multifunctional hubs that integrate industrial development, environmental sustainability, and social inclusion. Proczek M. and Garbarczyk M. [12] examine the role of the European Union in financing Blue Economy initiatives, focusing on investment mechanisms that support sustainable development of maritime regions.

The work of Vaca Cabrero J. addresses the development of sustainable ports through the integration of Blue Economy principles and the application of emerging digital technologies aimed at improving port management efficiency [13].

The work of Vaca Cabrero J. addresses the development of sustainable ports through the integration of Blue Economy principles and the application of emerging digital technologies aimed at improving port management efficiency. Research highlights that modern port systems should combine transport, energy, and environmental functions, acting as gateways to sustainable economic growth. At the same time, European studies emphasize the role of ports as potential energy hubs, particularly in the context of green hydrogen development and decarbonization of maritime logistics systems.

Ukrainian scholars [3; 5; 8; 9-11] have also contributed to the development of the Blue Economy concept, focusing on its national specifics and implementation challenges. Studies by Slizhe M., Berlinsky N., and El Hadri Y. Salinity [8-9] examine the development of priority sectors of the Blue Economy in Ukraine and emphasize the importance of marine resources in ensuring economic growth. At the same time, analytical materials and reports highlight the need for transforming Ukraine’s maritime sector in accordance with global sustainability trends. However, these works mainly focus on macro-level aspects, while the role of port logistics as an integrated system within the Blue Economy remains insufficiently explored.

A significant body of research is devoted to the issues of sustainable development and circular economy in the maritime sector. Navrozova Y. [5] proposes methodological approaches to assessing the level of sustainable development of maritime transport enterprises, emphasizing the need for comprehensive evaluation of economic, environmental, and social indicators.

The role of digital technologies in the transformation of port logistics is also widely discussed in scientific literature. Smentyna N. [10] highlights the importance of smart-port technologies, digital platforms, and automation in improving the efficiency of maritime transport processes. In addition, policy documents, including the Maritime Doctrine of Ukraine and strategic roadmaps for the implementation of European Union regulations, define the

institutional framework for the development of sustainable and digitalized port systems. Nevertheless, despite the existing research, there remains a need for a comprehensive approach to integrating Blue Economy, circular economy, and digitalization principles into a unified model of port logistics development in Ukraine.

Formation of the objectives of the article. The purpose of this study is to substantiate the role of Ukraine's port logistics as a key driver of sustainable development within the framework of the Black Sea Blue Economy, taking into account modern global challenges, including climate change, transformation of supply chains, and wartime disruptions. Achievement of the stated objective involves examining the theoretical foundations of the Blue Economy in port logistics and substantiating the implementation of circular resource management principles.

Summary of the main research material. Ukraine's port logistics have traditionally developed according to the principles of a linear economic model, which has led to resource inefficiency manifested on two levels [5; 10; 11]:

1. Physical infrastructure is characterized by high energy intensity. Most port terminals and warehouse complexes depend on fossil fuels and outdated energy-consuming technologies. The insufficient implementation of onshore power supply (OPS) systems forces vessels to burn fuel oil while berthed, leading to localized pollution of coastal waters and air. This directly contradicts the principles of the blue economy, which require minimizing the negative impact on the marine environment.

2. Operational inefficiency of logistics processes. Military risks, as well as bureaucratic and digital gaps, result in significant increases in vessel idle time. This downtime is not only a financial issue (higher freight and insurance costs) but also a direct ecological loss: each additional hour of anchorage or berth waiting time translates into additional tons of burned fuel and emissions. Within the framework of the blue economy, inefficient logistics become environmentally unsustainable.

The concept of the Blue Economy, which is actively evolving within the policies of the European Union and the coastal states of the Black Sea, envisions an integrated approach to marine resource management, encompassing transport activities, energy, fisheries, tourism, biotechnology, and the study of marine ecosystems. In this context, Ukrainian seaports can function as integrative platforms for the interaction of various sectors, where the activities of maritime transport, research institutions, renewable energy, and coastal communities are consolidated and coordinated [2].

For instance, the use of port territories for the installation of solar and wind power facilities, the implementation of water and air purification systems, the utilization of ship and terminal waste, and the development of digital platforms for emission monitoring are not merely technical innovations, but practical tools for integrating environmental standards into logistics processes.

Accordingly, the next stage in the development of port logistics is the transition from the integration of environmental standards to systematic resource management, that is, the implementation of the principles of the circular economy.

The formation of a circular economy management system in seaports requires a comprehensive approach to the rational use of resources, optimization of material flows, and reduction of environmental impact (Figure 1). Key aspects of this process include the effective management of land resources, energy, waste, and infrastructure – all of which ensure the sustainable development of the port industry.

The circular economy in seaports affects land resource management, ensuring the rational use of territory. Moreover, it stimulates the adoption of environmentally safe solutions in the fields of transport and logistics, prompting a transformation of approaches to the design and modernization of port infrastructure. Energy resource management in seaports enhances energy efficiency and reduces the negative environmental footprint. Seaports are sources of various types of waste generated through dredging, construction, industrial operations, and ship activities. Historically, waste management in ports relied on primitive disposal methods, such as the use of nearby landfills or direct ocean dumping. However, with the growth of port infrastructure and maritime transport volumes, traditional waste management practices have become unacceptable, making it essential to adopt modern environmentally oriented strategies.

The contemporary concept of port waste management is grounded in the principles of the circular economy, which emphasize waste minimization and the reuse of waste as secondary resources. The introduction of innovative waste-handling methods, including reuse, regeneration, and recycling, not only reduces environmental

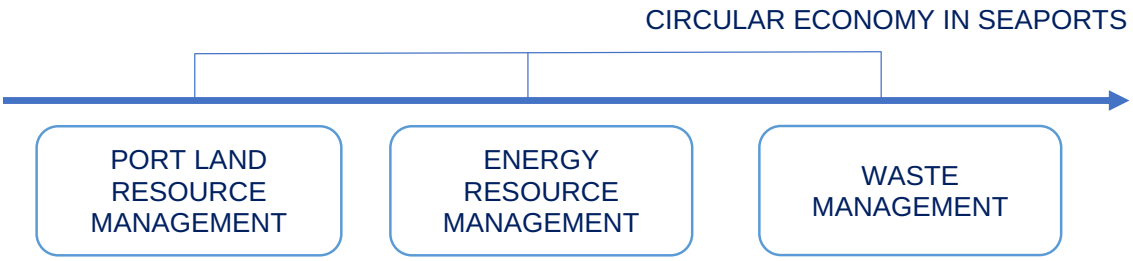

Figure 1. Circular Economy in Seaports

Source: compiled by the authors based on [4; 11]

pressure but also improves the economic efficiency of port operations [4; 11].

Comprehensive port waste management involves a range of measures, including the treatment of dredged material, utilization of industrial waste, operation of specialized Port Reception Facilities (PRF) for ship-generated waste, and the implementation of high-tech recycling systems [6].

The construction of high-efficiency PRFs and the development of mechanisms to incentivize their use are key elements of the waste minimization strategy and the integration of circular approaches into port waste management systems. The implementation of such infrastructural solutions contributes to a reduction in ship waste discharges into the marine environment.

The logistics dimension of sustainable port development deserves special attention, as it is through efficient transport and logistics processes that carbon footprint reduction, energy conservation, and cost optimization can be achieved.

Intelligent cargo flow management systems, the automation of customs procedures, and the use of big data for forecasting vessel and container movements all help reduce idle time, fuel consumption, and environmental impact.

For Ukrainian ports, particularly Odesa, Chornomorsk, Pivdennyi, and Izmail, this represents an opportunity not only to increase competitiveness but also to develop a new management model aligned with the principles of green logistics. In the context of post-war reconstruction, Ukraine's maritime logistics must become not only a driver of economic growth but also a key component of environmental security and international integration. Port restoration cannot follow outdated industrial models; rather, it must transition toward circular models, in which resources, waste, energy, and transport flows are interconnected within a closed cycle (Figure 2).

Installing solar panels on warehouse roofs, using electric tractors and hybrid cranes, implementing wastewater treatment systems, and adopting digital energy monitoring platforms these are concrete directions forming the foundation of "ports of the future."

It is equally important to emphasize the social dimension of sustainable port logistics. Ports create jobs, foster professional communities, support local populations, and stimulate small business development. The "sustainable port" concept also implies social responsibility, ensuring safe working conditions, equal opportunities, and partnerships with educational institutions for training a new generation of professionals.

An essential condition for sustainability is international cooperation. The Black Sea Blue Economy framework promotes joint initiatives among Ukraine, Bulgaria, Romania, Turkey, and Georgia aimed at marine ecosystem preservation, the development of green transport, and port digitalization.

By integrating into the European transport network, Ukraine can benefit from programs such as Black Sea Synergy and the European Green Deal to finance port eco-modernization, develop joint logistics hubs, and establish digital corridors connecting maritime and rail systems.

An additional direction of progress is the introduction of the "ports as energy hubs" concept, where port logistics are combined with renewable energy generation. Black Sea ports possess significant potential for the development of offshore wind energy, hydrogen production, and its export to the EU. Integrating energy and logistics processes helps reduce dependence on fossil fuels, stabilize regional energy balances, and enhance the economic resilience of port communities.

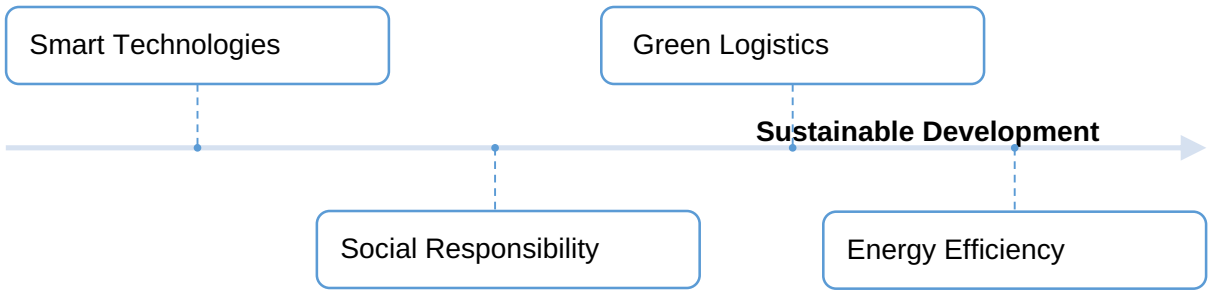

Figure 2. Key Aspects for Sustainable Development of Port Logistics

Source: compiled by the authors

Beyond technological and environmental transformation, the effective development of port logistics within the Blue Economy framework requires strengthening institutional and governance mechanisms. In particular, the coordination between port authorities, customs services, environmental agencies, and private operators remains a critical factor influencing the overall efficiency of maritime logistics systems. Fragmentation of responsibilities often leads to delays in decision-making and weak implementation of sustainability initiatives, which reduces the effectiveness of even advanced technological solutions.

Another important dimension of sustainable port development is resilience management. Modern ports must be capable of adapting to external shocks, including geopolitical instability, supply chain disruptions, and climate-related risks such as rising sea levels and extreme weather events. In this context, resilience becomes a strategic component of port competitiveness, requiring the development of adaptive infrastructure, diversified logistics routes, and flexible operational models that ensure continuity of maritime flows under uncertain conditions.

Environmental governance and ESG integration are also becoming increasingly important for the modernization of port systems. International investors and financial institutions increasingly prioritize sustainability indicators when evaluating infrastructure projects. Therefore, the implementation of ESG standards in port logistics not only improves environmental performance but also enhances access to international financing and strengthens the investment attractiveness of Ukrainian ports in the global maritime market [1; 6; 7].

Figure 3 illustrates the Blue Economy model in port logistics, combining strategic sustainability objectives with the operational principles of circular economy.

Human capital development plays a decisive role in ensuring the long-term sustainability of port logistics systems. The transition to digitalized, green, and circular port models requires new competencies in logistics management, environmental engineering, data analytics, and maritime digital technologies. Cooperation between ports, universities, and training centers is therefore essential for building a qualified workforce capable of supporting the transformation of Ukraine's maritime sector in line with global Blue Economy standards.

Conclusions. This study has examined the transformation of Ukraine's port logistics within the framework of the Black Sea Blue Economy and sustainable development paradigm. It has been demonstrated that the current functioning of Ukrainian seaports is still largely based on a linear development model characterized by high resource consumption, environmental pressure, and operational inefficiencies. The research substantiates the necessity of transitioning toward a circular and digitally enabled port logistics system that integrates environmental, economic, and technological dimensions into a unified development model.

The study has achieved several key outcomes. It has systematized the conceptual foundations of Blue Economy application in port logistics, emphasizing the role of seaports as multifunctional nodes that combine transport, energy, environmental, and digital functions. It has identified the main directions of transformation, including the integration of renewable energy sources, implementation of digital platforms such as Maritime Single Window, and deployment of intelligent logistics systems aimed at reducing emissions, improving operational efficiency, and enhancing infrastructure resilience. The research has highlighted the importance of circular

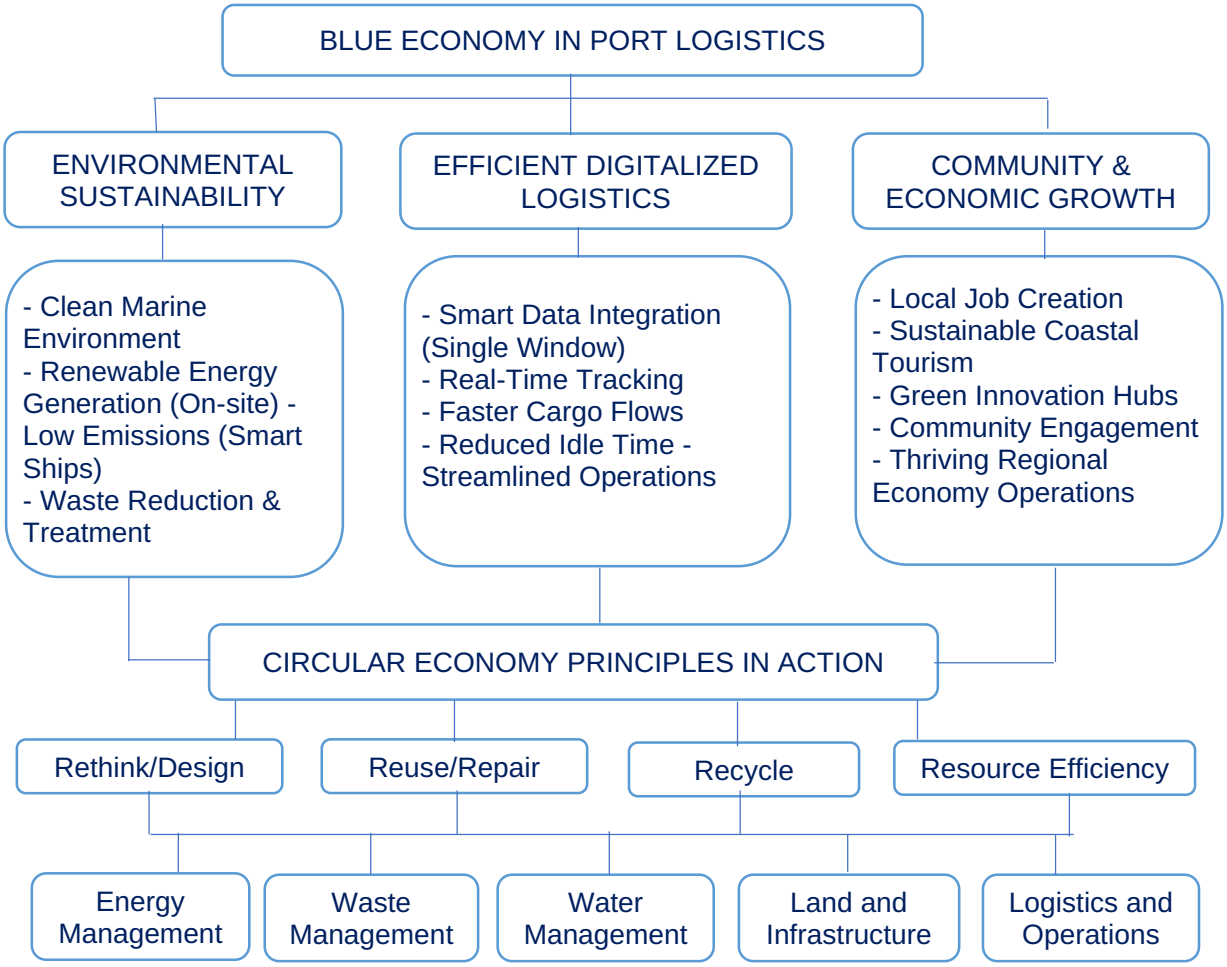

Figure 3. Conceptual model of the Blue Economy in port logistics

Source: compiled by the authors

economy principles in port waste management, energy use, and land resource optimization, demonstrating their role in improving both environmental performance and economic efficiency of port operations.

The study has shown that sustainable port development cannot be achieved solely through technological modernization. It also requires institutional coordination, ESG integration, resilience planning, and human capital development. These factors collectively determine the ability of port systems to adapt to external shocks, attract investment, and ensure long-term competitiveness within the European and global maritime space.

Future research should focus on the development of quantitative models for assessing the effectiveness of circular and Blue Economy mechanisms in port logistics. Particular attention should be given to measuring carbon reduction impacts, evaluating the economic efficiency of green port investments, and analyzing the scalability of digital port governance systems in different operational environments. Further studies may also explore comparative international practices of “smart green ports” to identify best implementation strategies for Ukraine’s post-war maritime recovery and integration into European logistics networks.

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