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TRANSFORMATION OF UKRAINE'S PORT LOGISTICS UNDER MARTIAL LAW: DRY PORTS, SEAPORTS, AND MULTIMODAL SOLUTIONS

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**ТРАНСФОРМАЦІЯ ПОРТОВОЇ ЛОГІСТИКИ УКРАЇНИ В УМОВАХ ВОЄННОГО СТАНУ:
СУХІ ПОРТИ, МОРСЬКІ ПОРТИ ТА МУЛЬТИМОДАЛЬНІ РІШЕННЯ**

The article examines the specifics of the transformation of Ukraine's port logistics under martial law, analyzes changes in the functioning of seaports and dry ports, and assesses the role of multimodal solutions in ensuring the continuity of logistics processes. Within the scope of the study, the specifics of the transformation of Ukraine's port logistics under martial law are considered, with attention drawn to the fact that it is characterized by the rapid adaptation of infrastructure and organizational processes to new types of constraints and risks, including the blockade of seaports, destruction or damage to infrastructure, increased security risks, limited throughput capacity, disruptions in transport corridors, and the need to adapt to new logistical and economic conditions. It is stated that the specifics of the

transformation of Ukraine's port logistics under martial law are shaped by: changes in port infrastructure (including the reorientation of logistics capacities and spatial decentralization of port functions); restructuring of operational processes (including a narrowing of the range of cargo handled and adaptation of technological and organizational procedures to security requirements); diversification of transport routes (specifically, reducing logistical dependence on a single route or port); and increased resilience of logistics chains (strengthening the system's ability to maintain continuity of transportation and cargo delivery). In fact, the analysis of such transformations allows us to conclude that their result is the expansion of the basis for strategic decision-making. Under conditions of sufficient scientific coverage of the specifics of port logistics, public authorities and logistics operators can develop well-grounded recommendations for the optimal use of dry ports, seaports, and multimodal solutions, as well as for enhancing the overall efficiency, safety, and resilience of the logistics system. Future research prospects lie in developing scientifically grounded recommendations and models for the optimal use of dry and seaports, as well as in multimodal logistics solutions, to enhance the efficiency, safety, and resilience of Ukraine's logistics.

У статті розглядається специфіка трансформації портової логістики України в умовах воєнного стану, аналізуються зміни у функціонуванні морських і сухих портів, а також оцінюється роль мультимодальних рішень у забезпеченні безперервності логістичних процесів. У межах дослідження розглянута специфіка трансформації портової логістики України в умовах воєнного стану та звернено увагу на те, що вона характеризується швидкою адаптацією інфраструктури та організаційних процесів до нових за характером обмежень і ризиків, серед яких блокування морських портів, руйнування або пошкодження інфраструктури, зростання безпекових ризиків, обмежена пропускна спроможність, перебої у роботі транспортних коридорів та необхідність адаптації до нових логістичних і економічних умов. Констатовано, що специфіка трансформації портової логістики України в умовах воєнного стану формується під впливом: змін в інфраструктурі портів (пов'язаних із переорієнтацією логістичних потужностей та просторовою децентралізацією портових функцій); перебудови операційних процесів (що передбачає звуження номенклатури вантажів, які підлягають обробці, а також адаптацію технологічних і організаційних процедур до посилених безпекових вимог); диверсифікації транспортних маршрутів (спрямованої на зменшення логістичної залежності від одного маршруту або порту); підвищення стійкості логістичних ланцюгів (що полягає у зміцненні здатності логістичної системи забезпечувати безперервність перевезення та доставляння вантажів). Фактично, аналіз таких трансформацій дозволяє констатувати, що їх результатом є розширення бази для стратегічного прийняття рішень. В умовах достатнього наукового висвітлення специфіки портової логістики органи управління та логістичні оператори отримують можливість формувати обґрунтовані рекомендації щодо оптимального використання сухих портів, морських портів і мультимодальних рішень, а також щодо підвищення ефективності, безпеки та стійкості логістичної системи загалом. Перспективи подальших досліджень полягають у розробці науково обґрунтованих рекомендацій і моделей оптимального використання сухих та морських портів, а також мультимодальних логістичних рішень для підвищення ефективності, безпеки та стійкості логістики України.

Key words: multimodal solutions; changes in port infrastructure; restructuring of operational processes; transport routes; seaports; port logistics.

Ключові слова: мультимодальні рішення; зміни портової інфраструктури; перебудова операційних процесів; транспортні маршрути; морські порти; портова логістика.

PROBLEM STATEMENT

The full-scale military aggression represents a significant challenge for Ukraine's port logistics, as prior to the war, seaports handled over two-thirds of the country's total foreign trade cargo turnover, including the main volumes of exports of agricultural, metallurgical, and raw materials products, and ensured Ukraine's effective integration into the global and regional transport-logistics networks of the Black Sea-Mediterranean basin, European trade corridors, and international supply chains. However, the prolonged state of martial law, the blockade of key seaports such as Mariupol, Berdyansk, and a significant portion of the port in Odesa, the destruction or damage

of port terminals, berths, transshipment and warehouse complexes, as well as the increased security risks, have caused substantial transformations in logistics regarding the organization of cargo storage and movement.

In these conditions, the development of dry ports as domestic logistics hubs has become particularly relevant. These hubs provide concentration, storage, customs clearance, and redistribution of cargo flows in safer regions of the country, followed by their shipment to external markets. At the same time, there is a partial reorientation of seaport operations toward handling a limited range of cargoes, primarily export-oriented raw materials, operating under special security regimes, and using

temporary logistics corridors. Another important aspect of adapting port logistics has been the development of multimodal logistics solutions involving rail, road, and river transport, which have contributed to diversifying transport routes, reducing dependence on maritime infrastructure, and enhancing the resilience of logistics chains under martial law conditions.

ANALYSIS OF RESEARCH AND PUBLICATIONS

The features of the modern development and transformation of Ukraine's port logistics are examined in the works of Demchenko B., Kononenko Zh. [3], Radko V.I., Svinous I.V., Segeda S.A., Satyr L.M., Bartkiv L.H. [5], Kharenko V.Yu., Skrypnyk N.Ye. [6], Martsenyuk V.V., and Martsenyuk M.V. [4]. These scholars analyze key risks and challenges, such as the partial or complete inaccessibility of traditional ports due to military actions and mine hazards in the water area; instability of rail, road, and river routes caused by combat operations or temporary closures; limited throughput capacity of port infrastructure; destruction of warehouses and terminals; increased security risks for personnel and cargo; and the need for rapid adaptation of logistics processes to changing economic and geopolitical conditions.

At the same time, the specifics of the transformation of Ukraine's port logistics under martial law have not received sufficient coverage in the scientific literature. In particular, there is inadequate attention to the features of Ukraine's port logistics transformation, particularly regarding dry ports, seaports, and multimodal solutions, which creates a number of challenges for both scientific research and practical planning.

As a result, a limited basis for strategic decision-making has been formed—management authorities and logistics operators lack sufficiently scientifically grounded recommendations on the optimal use of dry ports and the

organization of multimodal routes. There is also an insufficient assessment of adaptation measures' effectiveness, which, due to the absence of a systematic analysis, complicates determining which measures enhance logistics resilience and which fail to produce the expected effect.

FORMULATION OF THE ARTICLE'S OBJECTIVES

The article examines the specifics of the transformation of Ukraine's port logistics under martial law, analyzes changes in the functioning of seaports and dry ports, and assesses the role of multimodal solutions in ensuring the continuity of logistics processes.

THE PAPER MAIN BODY

Within the scope of the study, the transformation of port logistics is examined through the lens of a comprehensive restructuring of the system for handling, storing, and transporting cargo in ports and their associated transport chains. In this context, the authors agree with Kharenko V.Yu. and Skrypnyk N.Ye. [6] that direct indicators of this process include the adaptation of port logistics to new economic, technical, security, or geopolitical conditions—for example, the gradual transfer of some operations from seaports to domestic dry ports, which allows for the continuation of grain exports even when key Black Sea ports are blocked.

Within this framework, the overall process of transforming Ukraine's port logistics under martial law is characterized by the rapid adaptation of infrastructure and organizational processes to new constraints and risks, including the blockade of seaports, destruction or damage to infrastructure, increased security risks, limited throughput capacity, disruptions in transport corridors, and the need to adapt to new logistical and economic conditions.

In practice, the main directions of change include (see Figure 1):

1. Changes in port infrastructure, which we interpret as the process of modernizing, adapting, and reorienting physical facilities and technical systems that ensure the handling, storage, and movement of cargo, with the aim of improving the efficiency, safety, and resilience of logistics operations under new conditions.

2. Restructuring of operational processes, which we interpret as the process of changing the methods and sequence of performing all main cargo operations (reception, handling, storage, dispatch) to adapt to new conditions, with the goal of ensuring logistics efficiency, safety, and resilience.

General characteristic of transformation: expressed through directions that identify the nature of changes or restructuring in port logistics in order to ensure its more effective functioning under new conditions.

Direction: Changes in port infrastructure

Direction: Restructuring of operational processes

Specifics: Development of dry ports, modernization of warehouses, temporary logistics corridors.

Specifics: Handling a limited range of cargo in seaports, operating under special security regimes.

Specifics of transformations:

Comprehensive restructuring of the system for handling, storing, and transporting cargo in ports and their associated transport chains.

Direction: Diversification of transport routes

Direction: Enhancing the resilience of logistics chains

Specifics: Active use of multimodal solutions involving rail, road, and river transport

Specifics: Ability to maintain international transport operations even under challenging conditions with limited access to traditional ports

General characteristic of transformation: expressed through directions that identify the nature of changes or restructuring in port logistics in order to ensure its more effective functioning under new conditions.

Figure 1. Directions of the transformation of Ukraine's port logistics under martial law

Source: developed based on [1–3; 5].

3. Diversification of transport routes, which we interpret as the process of creating and using alternative cargo transport paths involving different types of transport, aimed at reducing dependence on a single route or port and increasing the resilience of the logistics chain.

4. Enhancing the resilience of logistics chains, which we interpret as strengthening the logistics system's ability to maintain the continuity of transportation and cargo delivery even under external constraints, crisis situations, or disruptions to traditional routes.

In simple terms, this refers to adapting the entire cargo handling and delivery chain — from reception and storage to transportation and dispatch — so it continues to operate effectively under new conditions, even if traditional ports are only partially operational or at risk.

The most significant change in logistics infrastructure is the reorientation of logistics capacities and the spatial decentralization of port functions. In particular, these key changes are driven by the development of dry ports — inland logistics centers located outside high-risk security zones. This is because such logistics facilities have taken over some of the traditional functions of seaports, including not only cargo storage and customs clearance but also the consolidation and distribution of cargo flows. This shift aims to reduce the burden on port-side infrastructure and enhance the overall resilience of the logistics system.

It should be noted that within the defined functional changes, the creation and modernization of dry port warehouse infrastructure are underway, aimed at establishing or increasing capacities for the temporary storage of grain, metal products, containerized, and bulk cargoes. Warehouses are being adapted to handle various cargo types through the installation of universal container racks, movable partitions, and adjustable storage zones for bulk and liquid materials, the implementation of modern accounting and control systems, and the strengthening of security and cargo protection requirements.

Vivid examples of such transformations include the development of the Chornotysiv Terminal (Zakarpattia Region) and Euroterminal LLC (Odesa Region), which operate or are planned to operate as multimodal logistics hubs equipped with modern warehousing and transshipment capacities for various types of cargo. This helps ensure the continuity of logistics processes and reduces regional dependence on seaports under the challenging conditions of martial law.

Among other, more innovative and noteworthy examples, special attention should be paid to the project for establishing a cluster of three dry ports in the village of Horonda, Mukachevo District. The first dry port is planned as the Horonda Platform multimodal logistics hub focused on grain exports to EU countries; the second is being developed by the Odesa-based agricultural holding DMV Group; and the third is designed as a multimodal

Table 1. Components of the transformation of dry port warehouse infrastructure under martial law

Components of Transformation	Characteristics and content of transformational changes	Specifics under Martial Law Conditions	Examples of transformation
Expansion of temporary storage capacities	Expansion of warehouse space and capacities to accumulate cargo due to uneven logistics flows, transportation delays, and limited access to seaports.	Creation of reserve warehouse capacities that can be rapidly engaged or released depending on changes in routes and cargo flow intensity.	Chornotysiv Terminal (Zakarpattia region), Euroterminal LLC (Odesa region).
Adaptation of warehouses to various cargo types	Re-equipment of warehouse facilities for storing agricultural, general, containerized, and bulk cargo.	Use of modular and universal warehouse solutions, allowing the functional purpose of warehouses to be quickly adjusted.	Chornotysiv Terminal – universal racks and adjustable storage zones for bulk and liquid cargo
Implementation of modern accounting and control systems	Implementation of digital warehouse management systems (WMS), automated accounting, and cargo movement monitoring.	Ensuring prompt management decision-making based on up-to-date data on cargo volumes, directions, and condition.	Use of WMS at Chornotysiv Terminal and Vinnytsia Container Terminal
Strengthening of security and cargo protection requirements	Introduction of physical, technical, and fire safety systems, access control, and video surveillance.	Focus on minimizing the risks of cargo loss and damage under conditions of increased danger and instability of logistics routes.	Video surveillance cameras, access control, and fire safety systems at Chornotysiv Terminal and Euroterminal LLC.

Source: developed based on [1—3; 5].

terminal for liquid bulk cargoes and a petroleum product storage base with a bioethanol blending facility, initiated by the Poltava-based energy group of companies "Nadiia" [9].

So, focusing on the transformation components outlined by us (see Table 1) highlights their orientation toward enhancing the flexibility of warehouse solutions, with a particular focus on their ability to respond quickly to changes in cargo flow directions and volumes.

A separate, accompanying element of infrastructure transformation has been the use of temporary logistics corridors, with dry ports playing a key role as intermediate logistics hubs between producers, domestic transport routes, and the limited-access maritime infrastructure.

The restructuring of operational processes in Ukraine's seaports involves narrowing the range of cargo handled and adapting technological and organizational procedures to heightened security requirements. Seaports thus focus primarily on servicing strategically important and export-oriented cargo, including grains and oilseeds, their processed products, metallurgical goods, and certain types of raw materials. This approach optimizes limited infrastructure resources and reduces the risk of a complete halt in port operations.

At the same time, special security operating regimes are being implemented, which involve restructuring operational processes through enhanced access control to port areas, regulation of the timing of cargo handling operations,

Table 2. Specifics of restructuring operational processes under special security regimes in Ukraine's seaports under martial law

Component of Transformation	Characteristics and Content of Transformational Changes	Specifics under Martial Law Conditions	Examples of Transformation
Access to port areas	Enhanced access control to port zones, introduction of pass regimes, and restrictions on personnel and vehicle presence	Increased security of port infrastructure, personnel, and cargo	Access control and checkpoints at the ports of Odesa and Yuzhny; restrictions on third-party vehicle movement during active hostilities
Organization of cargo handling operations	Regulation of the timing of cargo handling operations considering the security situation	Reduction of risks during operations and ensuring process control	Implementation of variable terminal working schedules in Odesa, Yuzhny, and Chornomorsk according to ship movement restrictions and heightened risks
Intra-port logistics	Modification of logistics routes for cargo movement within ports, taking into account restrictions and security zones	Optimization of internal flows and minimization of potential threats	Introduction of separate routes for containers, grain, and hazardous cargo at Yuzhny port
Technological processes of cargo handling	Adaptation of technological operations to military and civil security requirements	Ensuring continuity of port operations under heightened risk conditions	Use of enclosed conveyor systems and automated warehouses in Chornomorsk; reduction of manual operations to enhance personnel safety

Source: developed based on [3—4; 6].

modification of logistics routes within ports, and adaptation of technological processes to military and civil security requirements. More specifically, the characteristics of the restructuring of operational processes under special security regimes in Ukraine's seaports are presented in Table 2.

These highlighted regimes underscore the growing importance of coordination among port administrations, carriers, and government authorities. Overall, the restructuring of operational processes aims to ensure the continuity of port operations under limited throughput capacity, enhance the resilience of logistics operations, and minimize risks to personnel, infrastructure, and cargo.

Diversification of transport routes under martial law involves the active use of multimodal logistics solutions to ensure the continuity of transportation for critical goods and raw materials, including grains, oilseeds, metallurgical products, fuels and lubricants, construction materials, and industrial cargo. Among the most common types of multimodal solutions actively used in Ukraine (see Table 3) are:

— Rail + road transport — advantages include reduced dependence on blocked seaports and flexible routing;

— Rail + river transport — advantages include bypassing blocked Black Sea ports and saving time and costs when transporting large volumes;

— Road + river transport — advantages include flexibility and rapid adaptation to changes in security or road conditions;

— Rail + road + sea transport — advantages include transport combinability, which allows optimization of delivery time and cost, and provides alternative routes if one mode is blocked.

— Dry port + rail + road transport — advantages include reduced pressure on seaports, increased logistics flexibility, and enhanced resilience of supply chains.

In practice, the use of multimodal logistics solutions reduces dependence on maritime infrastructure, which is partially blocked due to hostilities, and allows routes to be quickly adapted to changes in the security situation, ensuring stability in exports and domestic supply. The use of multimodal solutions provides several key benefits [1—3]:

1. Logistics flexibility — cargo can be redirected between different modes of transport based on route and port availability.

2. Reduced delivery time — route optimization minimizes downtime and cargo delays.

3. Supply chain resilience — alternative routes make logistics operations less vulnerable to blockages or damage to transport infrastructure.

4. Economic efficiency — combining

different transport modes reduces transportation costs while maintaining the regularity of supply.

In parallel with the outlined transformations, measures are being implemented to enhance the resilience of logistics chains, in particular, strengthening their ability to maintain international transport operations even under conditions

Table 3. Characteristics of Typical Multimodal Solutions Actively Used in Ukraine under Martial Law

Typical multimodal solutions	Main application scenarios
Rail + road transport	Grain or rolled metal is transported by rail to an inland dry port, and from there by road to warehouses or alternative ports on the Danube or in neighboring countries.
Rail + river transport	Cargo, such as construction materials or grain, is transported by rail to a river port on the Danube, then shipped via river to a port in Romania or Bulgaria, and from there by sea.
Road + river transport	Cargo is delivered by road to a port terminal on the Danube, and then shipped via river transport to external markets.
Rail + road + sea transport	Containers with industrial goods are transported by rail to a port city, then by road to a port on the Black Sea coast, and finally shipped by sea for export.
Dry port + rail + road transport	A dry port in an inland region of Ukraine receives cargo from seaports or production centers, carries out customs clearance and sorting, and then forwards the cargo by rail or road to consumers or alternative ports.

Source: developed based on [1—3; 5—7].

of limited access to traditional seaports [6—7]. This is achieved through the introduction of digital accounting and control systems that enable prompt responses to changes in cargo volumes and flow directions, thereby reducing the risk of downtime and losses.

In practice, the analysis of port logistics transformations allows us to conclude that their outcome is the expansion of the basis for strategic decision-making, due to the following capabilities:

- Justified planning of resource utilization;
- Prioritization of development directions, determining which multimodal routes or technological processes should be developed first;
- Forecasting of logistics flows and risks;
- Enhancing the system's resilience to crisis or emergency situations.

CONCLUSIONS

Within the scope of the study, the specifics of the transformation of Ukraine's port logistics under martial law are examined, with attention drawn to the fact that it is characterized by the rapid adaptation of infrastructure and organizational processes to new types of constraints and risks, including the blockade of seaports, destruction or damage to infrastructure, increased security risks, limited throughput capacity, disruptions in transport corridors, and the need to adapt to new logistical and economic conditions.

The main findings indicate that Ukraine's port logistics transformation under martial law is defined by four key factors: (1) adaptive changes in port infrastructure, including the reorientation and decentralization of port functions; (2) restructuring operational processes, with adjustments in the types of cargo handled and technological procedures to meet security requirements; (3) diversification of transport routes to minimize reliance on individual ports or corridors; and (4) enhancement of logistics chain resilience to maintain cargo transport continuity amid disruption. These findings provide a clearer understanding of the core shifts within the logistics system.

This analysis of these transformations expands the basis for strategic decision-making. Because only limited scientific coverage addresses the specifics of port logistics, management authorities and logistics operators need evidence-based recommendations to use dry ports, seaports, and multimodal solutions optimally, thereby enhancing the efficiency, safety, and resilience of the logistics system as a whole.

Future research should focus on developing scientifically grounded recommendations and models for the optimal utilization of dry and seaports, as well as multimodal logistics solutions, to further improve the efficiency, safety, and resilience of Ukraine's port logistics.

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