

Adapting Multimodal Transportation Infrastructure to Changing Transport and Logistics Routes



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ABSTRACT

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The main purpose of the article is to study the infrastructure of multimodal transportation in the context of changes in transport and logistics routes. The object of research is the infrastructure of multimodal transportation. The main issue of the study is to determine ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes. For this, a modern methodology of functional modeling was used. As a result, a model was obtained that, in a graphical language, represents the main aspects of the development of the multimodal transportation infrastructure in the context of changes in transport and logistics routes. The focus of the study falls on Ukraine and its transport infrastructure. The article explores the development of multimodal transportation infrastructure in the context of changing transport and logistics routes. Showing the loss of the size of cargo transshipment by the seaports of the annexation of the area. The features of the functioning of seaports in an aggressive environment are described. Empirically, the potential volume of cargo transshipment and the volume of exports by seaports for a single country under different conditions have been established. Empirically established the volume of losses of container handling of goods. The study is limited by taking into account the multimodal transportation infrastructure of only one country taken.

1. INTRODUCTION

Before the events of February 24, 2022, $\approx 75\%$ of Ukraine's foreign trade turnover was accounted for by seaports. From February 24 to March 2022, they were all blocked. At the end of March, only three ports started working. Some ports were unblocked at the end of summer 2022 thanks to a grain deal. However, these ports have significantly reduced their capacity compared to the pre-war.

Before the events of February 24, Ukraine monthly exported up to 5 million tons of agricultural products through its ports. However, now due to their blockade, the country can transport only about 0.5 million tons of grain per month. This figure can be increased to 2-3 million tons by increasing the capacity of transshipment terminals, as well as railway and logistics crossings at the borders with the EU countries.

In addition, until the 24th, 33% of exports and $\approx 10\%$ of GDP were provided by the mining and metallurgical complex. The metallurgical industry as a whole is export-oriented. However, in the conditions of the blocking of the Black Sea, the monthly loss of exports of metallurgical products from Ukraine reached \$420 million. Today, the possibilities for exporting metallurgical products by rail are limited, and the EU seaports, to which metallurgists have reoriented, are not able to process all cargo. Consequently, the discrepancy

between the infrastructure for the transportation and reloading of metallurgical products is another acute problem that needs to be addressed immediately.

Efficient logistics has a direct and close impact on the main indicators of the economic development of the state. In particular, the correlation coefficient between the Logistics Efficiency Index and GDP per capita (USD), calculated using the corresponding parameters of 40 countries of the world, is 0.873 points.

Understanding the scale of losses for the country's economy (and here we mean not only export earnings but also sales markets, foreign clients, etc.) as a result of blocking the ports of the Black and Azov Seas, the country's authorities are actively trying to look for new transport and logistics routes for export. In particular, at a meeting of experts on hydraulic engineering, they noted that in the context of the slowdown in ship inspections under the Black Sea Grain Initiative and the threat of unilateral refusal to implement the agreement, the Danube region remains the only stable route for the export of agricultural products from Ukraine and, as a result, an important element in ensuring world food security. One aspect of solving the problem is increased trade with the EU and new logistics on the western borders. Modernization and expansion of border infrastructure are one of the key elements of this strategy.

EU countries declare maximum and comprehensive support for Ukraine. Among them, they are pursuing a proactive policy in the context of finding and building new transport and logistics routes. Consequently, Ukraine should make fuller use of the opportunities that are opening up for it today. In the context of freight transport, in particular, this should manifest itself in the promotion of the development of multimodal transport infrastructure in Ukraine as part of the EU's integrated transport network.

The study considers all available types of routes within the transport infrastructure: rail, road, air transport, and sea.

The main purpose of the article is to study the features of the development of the infrastructure of multimodal transportation in the context of changes in transport and logistics routes. The object of research is the infrastructure of multimodal transportation. The structure of the article implies a review of the literature, a description of the methods used, a presentation of the main results of the study, their discussion, and the current conclusions. The main issue of the study is to determine ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes. For this, a modern methodology of functional modeling was used.

2. LITERATURE REVIEW

In the literature, studies of multimodal transportation and the development of multimodal transshipment infrastructure are represented by a wide range of fundamental and applied works. For example, theoretical issues of organizing multimodal transportation and developing the corresponding infrastructure were considered in the works of Dua and Sinha [1], Baykasotglu [2], Udo et al. [3].

The works of Fang et al. [4], Wong and Fuchs [5], Melnyk et al. [6, 7], and others are devoted to the issues of organization and management of multimodal transportation.

It is interesting to study a certain group of authors [8]. The researchers proposed mathematical modeling of the risks of multimodal transportation. The authors note that the introduction of their model in the organization of multimodal transportation, in particular, will allow for choosing the best logistics route in terms of security. However, the authors' study has not been tested on the example of real multimodal transportation. Of course, its results should be taken into account when planning new transport and logistics routes in the Ukraine-EU space. However, the possibility of taking into account the new geopolitical risk should be introduced into the mathematical model.

As it has been repeatedly indicated in the literature [9, 10], in the context of the intensive development of world trade and transport relations and global integration processes, it is important to increase the efficiency of multimodal transportation of goods between regions, countries, and continents, as well as to identify ways to introduce additional technologies on the way to creating a multimodal national company.

In the scientific and practical literature, it is noted that the creation of a multimodal company based on the principle of customer orientation, first of all, is carried out in accordance with the high standards of modern automation of all levels of logistics, technological and related processes that accompany the cycle of providing a wide range of services. The consumer to whom logistics services are provided is a component of the

cargo delivery system. From these positions, the parameters of the quality of service provision are determined [11-13].

Interesting questions are raised in the scientific literature on the topic of our article. For example, various authors note [14-17] that an important component of measures to ensure the quality of a comprehensive service is a powerful technical base. Therefore, in addition to technological improvements, it is necessary to carry out certain measures for the reconstruction, and development of the production base, including through investment. Of course, there are obstacles on the way to the development of container transportation logistics in the country that does not depend on the enterprise, namely: imperfect tariffs for transportation by rail; changing customs regulations; high rates and port fees, etc. But the introduction of logistics principles into management makes it possible to integrate the enterprise into the international transport network, as well as to meet the needs of the national economy at the modern level.

Today, the transport system of Ukraine has a low level of development of transport infrastructure to ensure the proper volume of multimodal transportation. Ukraine lacks a sufficient number of multimodal transport terminals. Due to insufficient state support and the lack of an investment-friendly climate, the construction of new and the development of existing multimodal infrastructure facilities is not taking place. Multimodal transportation should become the basis for the development of the transport system of Ukraine. The transport network should be balanced, resource- and energy-efficient, taking into account the harmonious development of highways, railways, inland waterways, and other transport infrastructure based on multimodality [18, 19].

The issues of developing the infrastructure of multimodal transportation were studied in the works of Liu et al. [20], Molero et al. [21], and Lizbetin [22].

It should be noted that despite the significant scientific interest in the literature on this topic, the search for a modern methodical approach to determining ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes remains relevant and new. This is presented in our article.

In Ukraine, applied research on the development of the infrastructure of multimodal transportation has not yet become widespread. First of all, this is due to the insignificant involvement of Ukraine in the world's multimodal transportation in the pre-war period. And the law on such transportation in Ukraine was adopted relatively recently - in November 2022.

Today's conditions will necessitate a review of existing research on multimodal freight transport. In particular, in the context of changing transport and logistics routes and the need to ensure global food security, it is relevant to search for ways to develop and increase the capacity of the multimodal transportation infrastructure in Ukraine as part of the EU's integrated transport network.

3. METHODOLOGY

In the study, theoretical and empirical methods of cognition are used in their dialectical combination. The main methods used in the study are statistical analysis, induction, graphical and analytical methods, methods for assessing structural dynamic shifts, comparisons, and the monographic method.

The study also uses the following assessment methods, in

particular: theoretical generalization and comparison, induction and deduction are used to reveal the content of multimodal transportation, identify and generally characterize the types of infrastructure for such transportation; synthesis and economic analysis - assessed the state and trends in the development of the infrastructure of multimodal transportation in the context of changing transport and logistics routes; grouping method - to assess the loss of cargo turnover in war conditions in the context of the types of multimodal transportation infrastructure; economic, statistical and cross-border comparisons to assess the trend in the development of multimodal transport infrastructure in the EU countries; regression analysis - to study the impact of logistics efficiency (according to the Logistics Performance Index) on the economic development indicators of the state (in terms of GDP per capita, USD); cartographic and graphical method - for visual presentation of individual research results.

Data collection and analytical procedures were carried out within the framework of official statistical data of Ukraine, the country that serves as the basis of the study, and Eurostat data. The study compared countries neighboring Ukraine, such as Romania, Hungary, and Poland.

Functional and graphical modeling to represent the basic model for the development of multimodal transportation infrastructure in the context of changing transport and logistics routes. For this, IDEF technologies were used. Through the methodology of functional modeling, the system under study is presented as a set of interconnected blocks aimed at achieving the main goal of TL-0 (Development of the infrastructure of multimodal transportation in the context of changing transport and logistics routes).

4. RESULTS OF RESEARCH

The object of the transport and logistics infrastructure,

which ensures the handling of goods in the process of transportation, is a cargo terminal. Depending on the type of transport used for the transportation of goods, the following types of multimodal terminals are distinguished: port/sea terminals (located on the territory (or nearby) of seaports, railway, domestic and airport terminals).

The multimodal transportation infrastructure includes a wide range of facilities: transfer stations, railway stations, airports and air terminals, sea (river) ports, container terminals, and logistics centers. To achieve the goal of the study, this paper will analyze the development and features of the functioning of:

- seaports. It is sea freight transportation that is the most popular and affordable type of multimodal transportation;
- "dry" ports - located on land, have rail and/or road links with the port (sea) terminal.

Ukraine has a wide range of multimodal transportation infrastructure facilities (Figure 1).

The largest in terms of throughput and cargo capacity are multimodal terminals located near seaports or on the territory of seaports (Figure 2).

In 2022, the EU remained the largest trading partner of Ukraine - the share of Ukrainian exports to the EU countries reached 63.2% (in 2021, the corresponding figure was 39.3%). In 2022, Ukraine increased its merchandise exports to the EU countries by 4.2% compared to 2021 (USD 26.8 billion to USD 28 billion, respectively), despite the fact that in 2022 Ukrainian exports decreased by 35.1%.

As of the beginning of 2023, in the western region of Ukraine, one of the largest (in terms of throughput and cargo capacity) infrastructure facilities for multimodal transportation is the Mostyska Container Terminal (Figure 3). Its design capacity today is 100,000 TEU. However, the operating company is working to increase the terminal's capacity to 200,000 TEU. On average, in 2022, the terminal was loaded at 65%.



Figure 1. Infrastructure of multimodal transportation in Ukraine

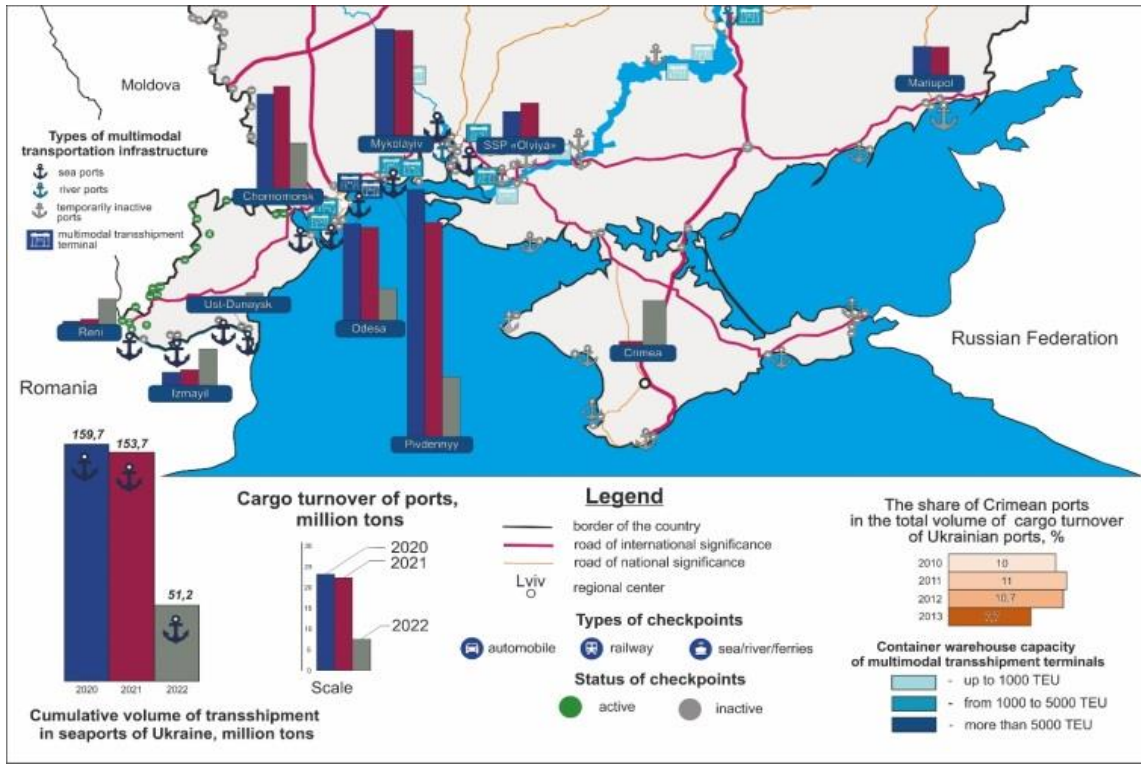


Figure 2. Infrastructure of maritime multimodal cargo transportation in Ukraine

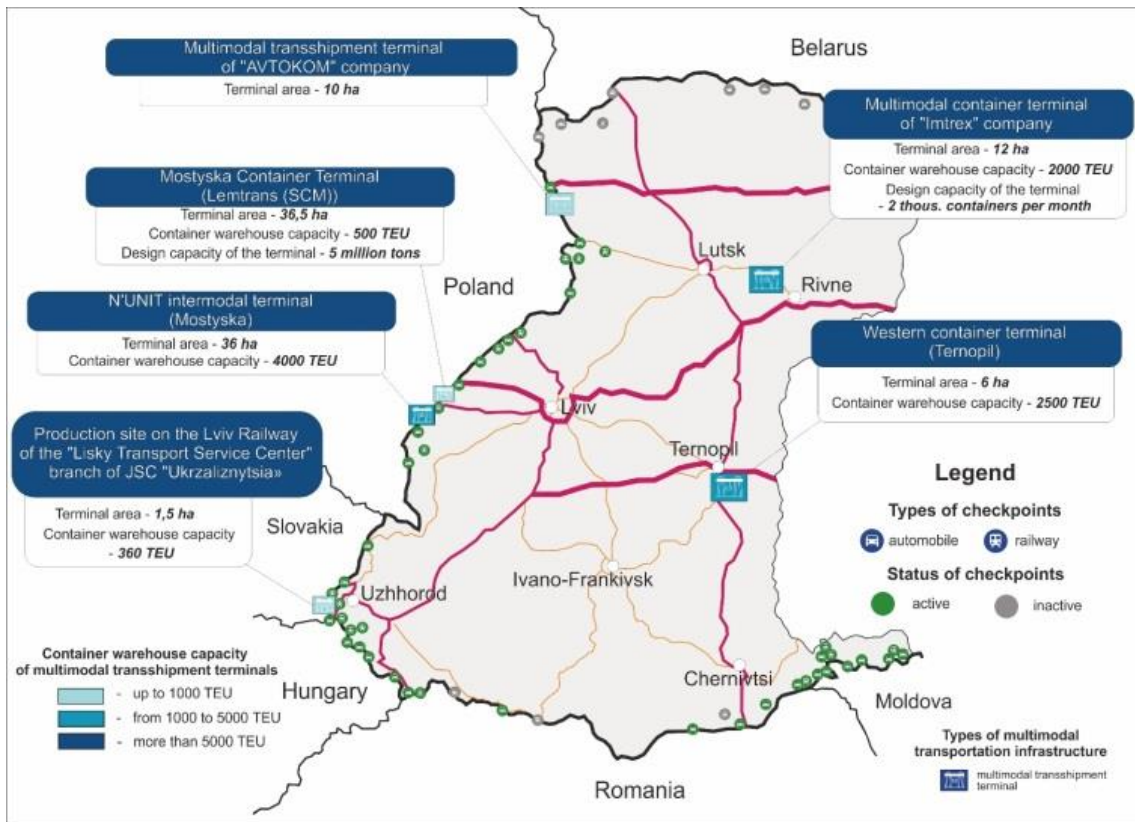


Figure 3. The infrastructure of overland multimodal freight transportation in Ukraine

In general, the network of inland ("dry") ports operates in close connection with the network of marine terminals. However, the challenges associated with changing transport and logistics routes, and the destruction of transport infrastructure necessitate an increase in the capacity of the western border crossings, and Danube seaports, as well as the development of infrastructure around them, including the

development of multimodal transshipment terminals.

The need to develop the infrastructure of multimodal transshipment terminals at the Danube ports is argued by the need to solve the problem of establishing exports for companies in the mining and metallurgical complex, whose logistics costs as a whole increased by 4-6 times, depending on products and enterprises, among other purely military

circumstances, is a consequence of increase in tariffs for freight rail transportation by 70%.

The development of the infrastructure of multimodal transportation in general for Ukraine can serve as one of the components of transport and logistics integration in the EU. Ukraine should make the most of the opportunities for the development of multimodal transportation, which will arise as a result of the implementation of infrastructure projects by the EU countries. For example Romania is renovating a wide track between Giurgiulesti and Galati. Thanks to the use of this route, Ukraine will be able to freely carry out cargo turnover with the Romanian port of Galati; Slovakia plans to create a railway

transport corridor from Ukraine to the river port in Bratislava for the transportation of grain along the Danube River; Moldova has signed a Memorandum of Understanding with Ukraine on the development of railway communication. This will help increase the transportation of Ukrainian export cargo, including to the ports of the Danube region.

Achieving TL-0, according to modeling technology, involves several elements, presented in the diagram in Figure 4.

In general, the main functional model of TL-0 is shown in Figure 5.

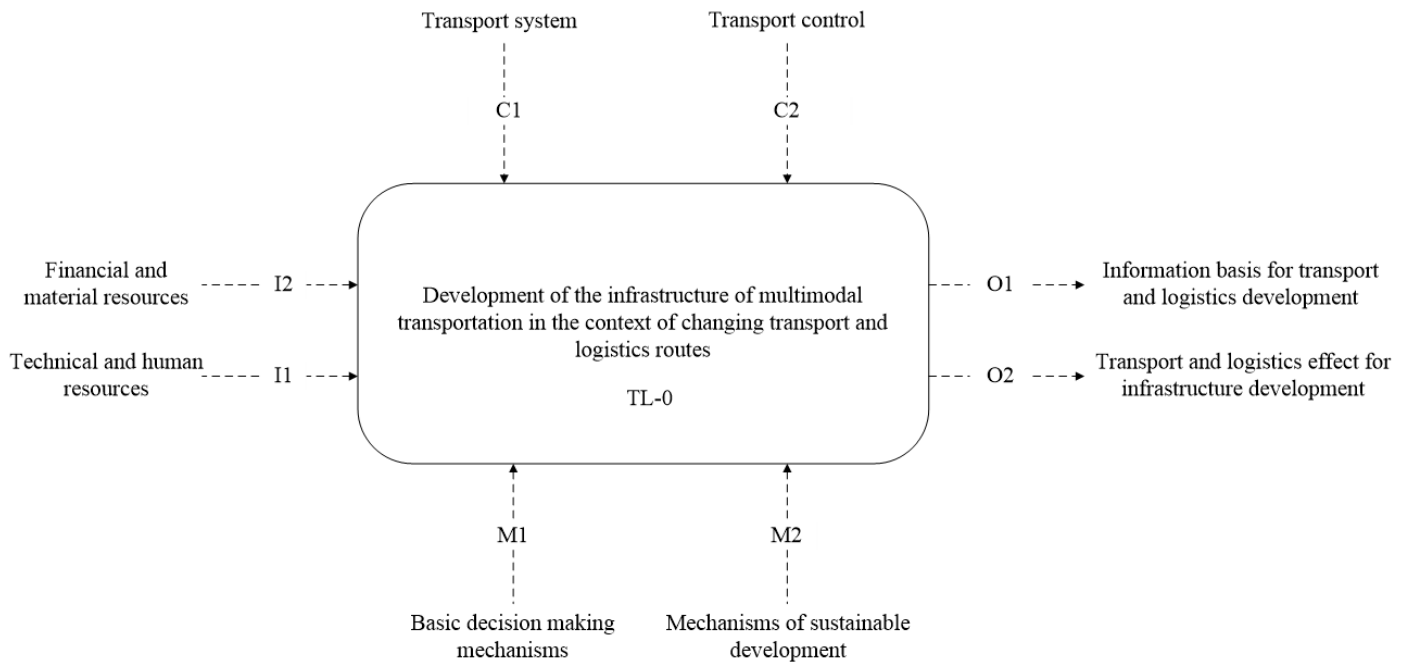


Figure 4. Graphical diagram of the results of achieving TS-0

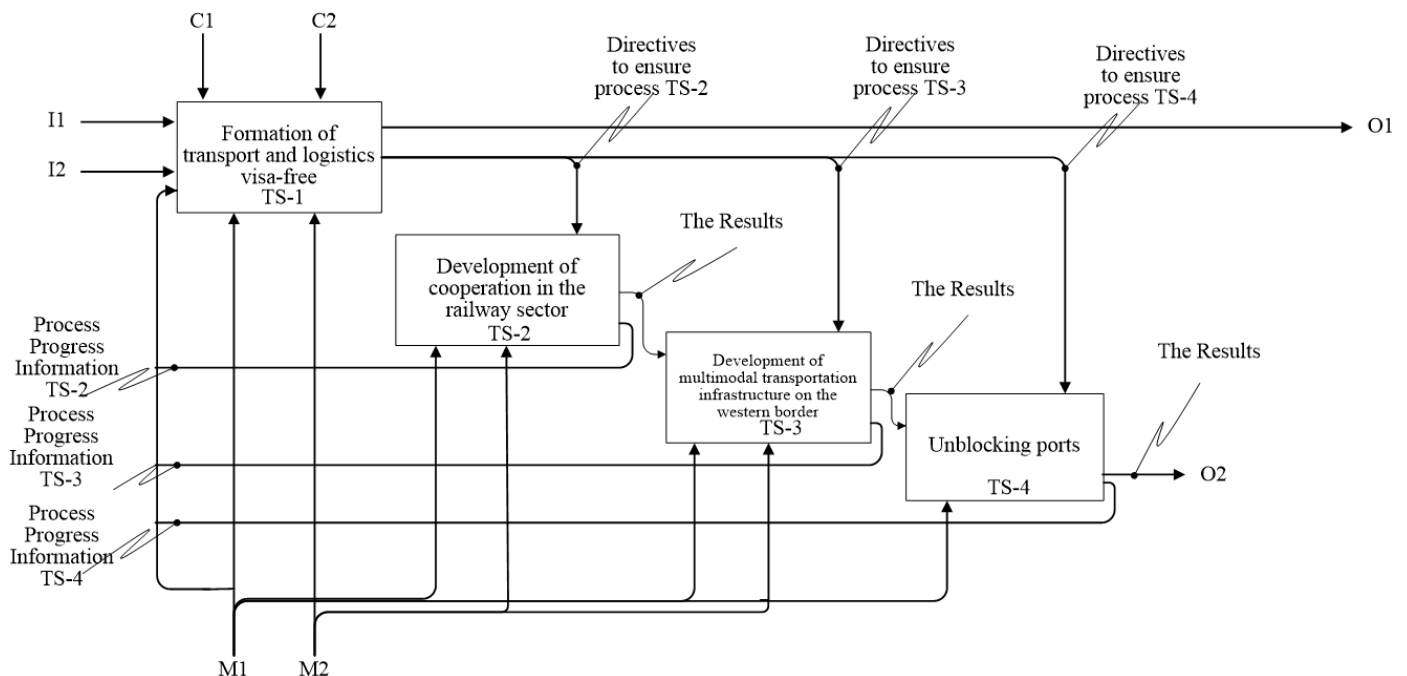


Figure 5. The main functional model of TL-0

Thus, to achieve TL-0, the following processes must be followed:

TL-1. Formation of transport and logistics visa-free. It is necessary to develop the concluded agreements (the so-called

“trade visa-free”, “transport visa-free”, “customs-free”, the EU initiative “Ways of Solidarity”, etc.), the operation of which, in the aggregate, will contribute to the establishment of alternative routes (both railway and automobile) export of Ukrainian agricultural products, and import of essential goods in the conditions of the blockade of seaports, speeding up the passage of Ukrainian goods across the border (including avoiding stops in the export of domestic products through automobile checkpoints), simplifying the procedure for documenting cargo at checkpoints one transit declaration and one guarantee for the movement of goods between Ukraine and 36 countries (EU countries, as well as the UK, Turkey, Serbia, North Macedonia, Iceland, Norway, Liechtenstein, and Switzerland)), simplifying the procedure for recognizing driver's documents, etc.

TL-2. Development of cooperation in the railway sector. Consultations are ongoing in government circles on the possibility of involving Ukraine in the Amber Train project and the creation of a regular rail freight line between Ukraine and the Baltic countries. For Ukraine, this may result, on the one hand, by strengthening its presence in the Baltic markets, and, on the other hand, by the possibility of using the ports of the Baltic Sea to export Ukrainian grain and metal products further to the world market. And Croatia offers its ports on the Adriatic coast for the transportation of Ukrainian grain to the countries of North Africa. However, the key point remains that the cargo to the ports of both the Baltic and Croatia will be delivered mainly by rail. Therefore, it is clear that rail freight transport will develop. This will require the modernization of the border infrastructure to increase the export capacity of Ukraine. And this will lead to an increase in demand for the services of multimodal transshipment terminals, as transport hubs and intermediaries between the Ukrainian seller and the European buyer.

TL-3. Development of multimodal transportation infrastructure on the western border. The development of multimodal transportation infrastructure on the western border of Ukraine is relevant and promising, given the possibility of including Ukraine in the New Silk Road, which connects Europe and China by container rail. In the summer of 2020, Ukrainian logistics companies have already begun to establish communications between Kyiv and other cities in China. Further from Kyiv, container trains followed through the territory of Belarus to the Brest-Malashevich border crossing on the Belarus-Poland border. However, today the transport and logistics routes that previously passed through the territory of Belarus are blocked. Obviously, containers from Asia can be reloaded in Western Ukraine and then sent to the EU countries. And in this context, Ukraine must provide European freight forwarders and customers with an efficiently functioning multimodal transportation infrastructure.

TL-4. Unblocking ports. The rapid reopening of the ports will be difficult due to the severely damaged infrastructure there. In the conditions of permanent growth of the population of the planet, and with it the demand for the products of the agro-industrial complex, the states of the world will strive to avoid a food crisis. In this context, Ukraine has a colossal export potential that needs to be realized here and now. And the economy needs foreign exchange earnings.

Firstly, to revive the functioning of the ports of the Danube and the multimodal terminals around them, it is necessary to deepen the operational bottom of the water areas of these ports. This will make it possible to receive cargo from large ships, improve the safety of navigation on the Danube, and maintain

the declared depths. In addition, the renewal of the Danube fleet and port transshipment infrastructure is required.

In general, multimodal transshipment terminals in Western Ukraine are well-equipped. It provides a wide range of customs brokerage services. However, there are obstacles in the context of the revitalization of the functioning of these facilities: difficulties with crossing the border by rail due to different track widths in Ukraine (1520 mm) and EU countries (1435 mm). As a result, at checkpoints across the state border, it is necessary to replace wagon bogies or move goods to wagons with the required wheel pair width. This leads to significant downtime, and additional costs and does not allow optimal use of the existing throughput of checkpoints; limited number and throughput of checkpoints across the state border capable of serving rail freight traffic. Thus, in Ukraine, there are only 13 cargo border crossings (4 units - with Poland, 3 units - with Moldova, and 2 crossings each - with Romania, Slovakia, and Hungary). Despite the declared potential capacity of the western crossings in the amount of 6.6 million tons per month, it is actually possible to use only 3.8 million tons per month or 57.8%; higher overall dimensions of the rolling stock of Ukraine in comparison with the EU. Thus, large Ukrainian wagons can damage tunnels, bridges, platforms, and other objects of the nearby transport infrastructure, which often makes it impossible for them to move on the European railway.

We would like to note that the results of the study we obtained contain a number of parts of innovation. First of all, it concerns the fact that by analyzing the transport infrastructure of Ukraine, one can see and prove that it has all the necessary opportunities to acquire a high level in terms of logistics.

A separate result, which has elements of innovation, is the proposed functional model of ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes.

5. DISCUSSIONS

Discussing the results of the study, it is necessary to determine what will contribute to the revitalization of the functioning of the multimodal transportation infrastructure in Ukraine.

Of course, in order to revive the functioning of multimodal transshipment terminals, firstly, it would be worth developing and approving a strategy for the development of multimodal transportation. Discussing our results, we emphasize that in this study we empirically proved the importance and prospects of developing the infrastructure of multimodal transportation. Therefore, we believe that the next logical (natural) step should be the adoption of a strategy for the development of multimodal transportation, including the development of appropriate infrastructure.

However, today, in the absence of a state strategy for the development of multimodal transportation, the revival of the functioning of multimodal transshipment terminals can be facilitated by the full implementation of state projects for the restoration and development of transport infrastructure.

Along with the development of state multimodal transshipment terminals, the economic losses of Ukraine as a result of the loss of control over the ports of the Sea of Azov and the decrease in the congestion of the ports of Odesa may partially minimize state assistance to the development of

private multimodal transshipment terminals on the Danube.

To revive the functioning of land multimodal transshipment terminals, it is important to eliminate the infrastructural constraints of rail transport. In this context, in cross-border cooperation in the western direction, the state should pursue a proactive policy in the context of the implementation of infrastructure projects related to the construction/restoration/extension of European routes through the territory of the border areas with the EU. In addition, it requires a solution to the issue of the overall dimensions of the rolling stock. Thus, large wagons can damage tunnels, bridges, platforms, and other objects of the nearby transport infrastructure, which often makes it impossible for them to move on the European railway. In May 2022, Hungary preliminarily agreed on the use of several types of Ukrainian wagons on certain routes of its railway network. We believe that at the state level, activities should be intensified to coordinate similar routes for Ukrainian railcars in other neighboring countries.

The existing theories and practical aspects in the selected issues have their place, however, discussing the results we obtained, it should be noted that they have a certain value in the framework of the development of the strategy of multimodal transportation. This is manifested through the presented functional model of ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes. Also, it should be noted in the discussion that all results are presented within the framework of one country - Ukraine. Today, geopolitical events can continue to affect the transport routes and infrastructure needs of Ukraine, and precisely thanks to the help of countries such as Poland and Romania, this will only increase the positive impact.

The presented limitations should be discussed separately. They are mainly presented in the form of taking into account only one country and its infrastructure. In the future, the framework of the study should be expanded and other countries should be taken into account.

6. CONCLUSIONS

As part of our study, we chose the transport and logistics specifics of Ukraine. In Ukraine, the infrastructure of multimodal transportation is still in the initial stages of development. This is due, firstly, to the long absence in Ukraine of institutional support for the implementation of this type of transportation, and secondly, to the insignificant involvement of Ukraine in the world multimodal transportation in the pre-war period. However, today the country faces a number of challenges in the field of cargo transportation: the temporary loss of ports, the temporary loss of the ports of the Sea of Azov, the blocking of the work of individual ports of the Black Sea, a strict inspection of ships on the Bosphorus when passing the so-called "grain corridor". As a result of the termination of the usual logistics chains, the volume of cargo transshipment, for example, by the seaports of Ukraine in 2022 compared to 2021, almost tripled.

Redirection of the flow of goods of Ukraine towards the EU, confirming the prospects and efficiency of such transport and logistics routes (in 2022 compared to 2021: commodity exports to the EU countries increased by 4.2% with an overall reduction of 35.1%; Danube ports handled three times more cargo).

Considering the scale of the losses of the country's economy and understanding the need to realize its export potential, preserve existing sales markets and supply chains, and replenish the budget with export earnings, Ukraine should make efforts to enhance the development of multimodal transportation infrastructure in the Ukraine-EU space.

The development of multimodal transportation infrastructure, in addition to a pronounced conical effect on the national economy, will help increase the country's competitiveness in the global transport services market, develop a network of transport corridors, and integrate transport infrastructure into the global transport system.

In this context, first of all, it is necessary to accelerate the implementation of measures for the development of multimodal transshipment terminals, provided for by the Recovery Plan of Ukraine. The government's policy to eliminate infrastructural restrictions on railway transport needs to be activated (implementation of infrastructure projects related to the construction/restoration/extension of European routes by the territory of the regions bordering the EU). In addition, the development and approval of a strategy for the development of multimodal transportation is relevant.

With the constant development of transport infrastructure, it is possible to strengthen food security. For example, with access to transportation across the sea, it is possible to deliver a significant amount of grain, as Ukraine exports.

The main result of the study is the presented functional model, which characterizes the key ways to develop the infrastructure of multimodal transportation in the context of changing transport and logistics routes.

The study is limited by taking into account the multimodal transportation infrastructure of only one country taken. The prospect of further research by the authors is to study the foreign experience of state assistance to the development of multimodal transportation infrastructure in the context of its application in Ukraine.

Further research should be devoted to conducting specific case studies on the impact of geopolitical developments on multimodal infrastructure and trade flows; forecasting infrastructure needs and requirements for the transport network under different scenarios of political and economic conditions; assessing the availability of funding and partnerships to support the development of multimodal infrastructure; evaluating the effectiveness of policies and regulations that support multimodal transport.

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