Designing The Location Of Multimodal Transport Terminals Under The Conditions Of The Socio-Economic Recovery Of Ukraine

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Abstract

In the conditions of high uncertainty, the question of determining the transport terminal location as an important link of the logistics system through which the movement of cargo flows becomes especially actual. This aspect significantly affects the logistics costs and the final price of the product for consumers. The conducted research shows the role of transport terminals in the organization of multimodal cargo transportation in the conditions of infrastructure reconstruction. A model for choosing a strategy for the multimodal transport terminal location was developed. It allows to optimize cargo flows. A model for estimating the expected effect of using the public-private partnership mechanism for the creation of a multimodal transport terminal was developed. It allows to choose the most effective financing mechanism and consider the stakeholders' interests. This approach can be used in the development of the infrastructure reconstruction strategy in the post-war period.

Keywords: logistics, financing, Public-Private Partnership, recovery, infrastructure, transportation, cargo flows, multimodal terminal, efficiency, strategy.

1. Introduction

In the conditions of socio-economic recovery of any country because of the military aggression of the Russian Federation, the problem of construction and reconstruction of multimodal transport terminals, through which the movement of the main international cargo flows, is exacerbated. At the same time, there is an increase in cargo flows due to the need to rebuild the destroyed territories, their support with humanitarian aid, etc., and due to a change in the routes of transport corridors. It should be noted that the reconstruction and modernization of the logistics infrastructure is one of the main factors contributing to the improvement of the socio-economic condition of any country.

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According to the project of the 2022 Draft recovery plan of Ukraine, the main priorities in the strategic stages of structural modernization and full integration into the EU are the development of a network of logistics multimodal terminals with the functions of integrated transport and logistics centers, the implementation of customs services and the use of modern digital logistics management solutions (Draft recovery et al, 2022). The European Commission supports Ukraine in every possible way in terms of integration into the EU Single Market through its joining the Connecting Europe Facility (CEF) program, which will allow attracting additional funding for the restoration of infrastructure (Connecting Europe Facility, 2023).

Also, the relevance of the research is confirmed by the fact that globalization processes contribute to the construction and development of modern multimodal transport terminals within the framework of integration into a single European transport system. During the formation of a network of multimodal transport corridors passing through the territory of Ukraine, there was a shift of the center for choosing the location of multimodal transport terminals from the center of the country to its western part and differentiation of transportation of the main export-import cargo flows by types of cargo. At the same time, the world community is interested in the expansion and reorientation of cargo flows to alternative transport corridors due to the impossibility of fully using the existing infrastructure of the seaports of Ukraine due to the military aggression of the Russian Federation. In particular, there was an intensification of work with the seaports of Romania, Poland, Germany, Slovenia and a number of other neighboring European ports, which made it possible to ensure effective management of supply chains.

2. Literature review

Zhang et al (2017) focused on developing a model of emission losses in multimodal ferry transportation that also considers the cost of travel.

Nong (2022) devoted his research to developing a hybrid model for distribution center location selection in all industries.

Cempírek et al (2021) focused on the study of delivery of parcels to the final link of the City Hub supply chain, considering the use of new technologies, the introduction of alternative fuels and environmental impact.

Kumar and Anbanandam (2019) considered the creation of a multimodal freight terminal as a lever for increasing the sustainability of freight transport. And in this context, they proposed a model for assessing the location of the terminal considering the social, technical, economic, environmental, and political dimensions (STEEP).

Naumov et al (2020) considered the functioning of multimodal transport terminals as a factor affecting the efficiency of service of material flows in the supply chain and the sustainability of the transport system. They proposed an approach to determine the optimal parameters of multimodal transport terminals with given parameters of input and output material flows.

He et al (2021) considered multimodal freight transportation as a factor in increasing the efficiency of the use of vehicles. They developed an approach to modeling multimodal freight transport networks, emphasizing their reliability assessment considering the possibility of random failures.

Zukhruf et al (2022) developed a model for optimizing the recovery of a transport network disrupted by a disaster, considering multimodal terminals for sending relief goods.

Archetti et al (2021) carried out an in-depth study of the use of optimization methods to solve various problems related to multimodal transportation.

Also, researchers consider planning problems in the context of logistics 4.0 to ensure the sustainable development of intermodal and multimodal transportation in an uncertain environment (Rasheed et al, 2022).

In their works, the above-mentioned authors provided an in-depth analysis of the activity of multimodal logistics centers in relation to their fields of research. However, these publications do not consider the modern role of multimodal transport terminals in the socio-economic recovery of the country in the post-war period. Therefore, this research becomes relevant and of practical significance. The conducted research is based on a comprehensive approach in determining the role of multimodal transport terminals in the development of the economy. This is also considered when building economic-mathematical models from the point of view of efficiency from the creation of a multimodal transport terminal, as well as the use of the public-private partnership mechanism as a source of funding.

The purpose of the study is to highlight and justify the role of multimodal transport terminals in the period of reconstruction of the infrastructure of Ukraine in the post-war period and to develop scientific and practical approaches to their design.

3. Methodology

The study was based on a systematic review of scientific sources on multimodal transport terminals, information from the official websites of the European Commission (Connecting Europe Facility), the Cabinet of Ministers of Ukraine (Draft recovery plan of Ukraine) and consulting companies (GMK Center, Razumkov Center). This allowed us to systematize the advantages and disadvantages of various cargo delivery schemes.

To justify the choice of location for a multimodal transport terminal, a comprehensive methodology combining quantitative and qualitative methods was used. It allowed building a multi-criteria optimization model that considered dual criteria: maximizing throughput and economic effect, minimizing route time and cargo handling costs. To formalize the problem, the Pareto optimality principle was applied, which allowed determining a compromise strategy for locating a multimodal transport terminal. An expert survey of 28 logistics specialists provided weighted estimates of the criteria and refinement of the model structure.

To detail the factor impact, an Ishikawa diagram (a method of critical information analysis) was used, the main purpose of which is to identify, classify, and visualize factors that may affect the results of activities, which allows for a deeper investigation of the structure of causes and contributes to making informed management decisions. It allowed dividing the factors influencing the determination of the location of a multimodal transport terminal into five groups, namely: infrastructure, economic, innovation, demographic and security. Additionally, limiting factors were considered: topological-resource, organizational-management and financial. To assess the risks, the risk priority number method was used, which was based on a three-component assessment: significance, probability of occurrence and probability of detection. It allowed using ABC analysis tools to rank critical impact factors. The riskiest criteria are “fighting” and “availability of transport corridors”. To finance the project, a public-private partnership mechanism has been proposed, which involves risk sharing, coordination of the interests of the parties, and the use of concession models (BOT, BTO, BOOT).

The project envisaged the legal implementation of EU norms on multimodal transportation, ensuring the integration of Ukraine into the European transport area. As a result of the study, a roadmap for decision-making on the location of the terminal was formed, considering strategic, institutional and security factors.

4. Results and discussion

Terminals are places where goods begin, end or are processed in the process of transportation (Rodrigue, 2020). From the position of the authors in the study, a multimodal transport terminal is understood as a multifunctional terminal complex located at the intersection of transport networks, which acts as an intermediary and integrator of cargo flows in the system of regional and global supply chains, providing complex and efficient logistics service. This definition reflects the most important functions of multimodal transport terminals as elements of logistics chains: loading and unloading of transport units, intermediate storage of goods; cargo consolidation and deconsolidation, necessary customs procedures, a full range of service and commercial and business services, etc.

Multimodal transport terminals are a critical element of the process of forming supply chains in the implementation of multimodal transportation in international and domestic connections, combining various cargo delivery schemes in order to meet customer requirements, the advantages and disadvantages of which are shown in Table 1.

Table 1: Advantages and disadvantages of cargo delivery schemes.

Types of transportation	*Advantages*	*Disadvantages*
Complete transportation of cargo - direct delivery of cargo "door to door" of all shapes and sizes from the cargo owner to the consignee	Lack of dependence on other market participants Fast delivery speed	Expensive transportation
Loaded transportation - transportation is performed in the "door-to-door" format by picking up cargo from different customers and different points of departure - in one car or container	Lowering the cost of transportation	Dependence on other shippers
Consolidated transportation of goods - a scheme of freight transportation, in which the order of different consignors is consolidated in one warehouse or terminal and is stored until the necessary amount of cargo is collected for shipment	Lowering the cost of transportation	Dependence on other shippers Long delivery time
Multimodal cargo transportation		
door-to-door solutions by combining more than one mode of transport to any point in the world, combining previous cargo transportation schemes		

Source: systematized by the authors based on He et al (2021), Naumov et al (2020), Nong (2022), Zukhruf et al (2022)

In Ukraine, there are multimodal terminals located close to state border crossing points and intended for international cargo transportation (Figure 1). The available actual capacity of multimodal transport terminals located near the borders is concentrated in the West of Ukraine. Their orientation reflects multimodality in the use of mainly rail and road transport. Today, most cargo flows are reoriented to these types of transport, which is due to the lack of air cargo transportation and the limited functioning of Ukraine's waterways due to military actions and the occupation of part of the territory. In 2022, the

most loaded Ukrainian goods were the Polish ports of Gdansk, Gdynia, Szczecin, as well as the Romanian port of Constanta (How the export logistics of iron and steel companies has changed in 2022, 2022).

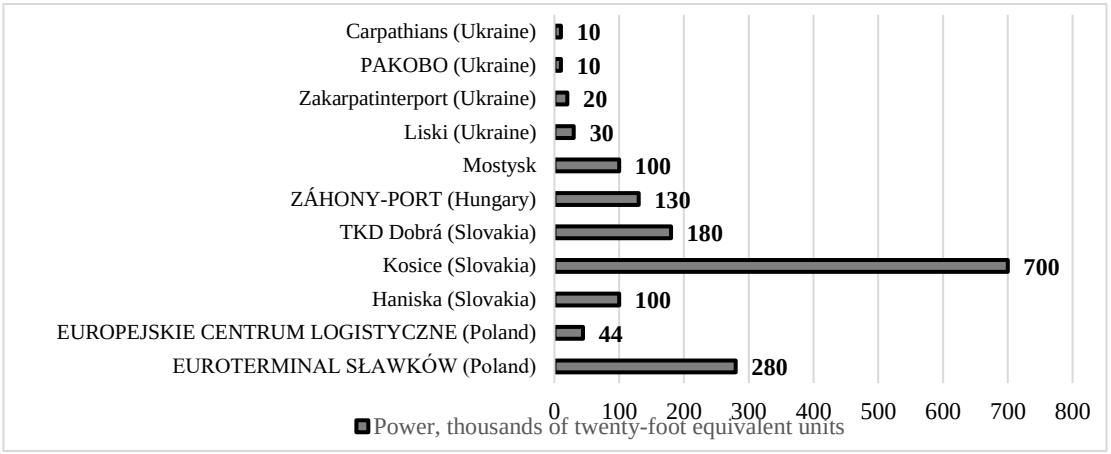

Figure 1: Capacity of multimodal terminals on the border with Ukraine
Source: built by the authors based on (Ukraine Sea Ports Authority, 2023).

In connection with the growth and reorientation of cargo flows in international transport corridors, as well as significant damage and destruction of transport infrastructure, there is a need for additional construction or reconstruction of multimodal transport terminals and a change in the approach to the strategy of choosing their location. In 2022, the modern Mostysk Container Terminal (Figure 2) with a design capacity of 100,000 TEU (twenty-foot equivalent unit) was opened, which performs a distribution function and connects shippers and consumers on the European market.

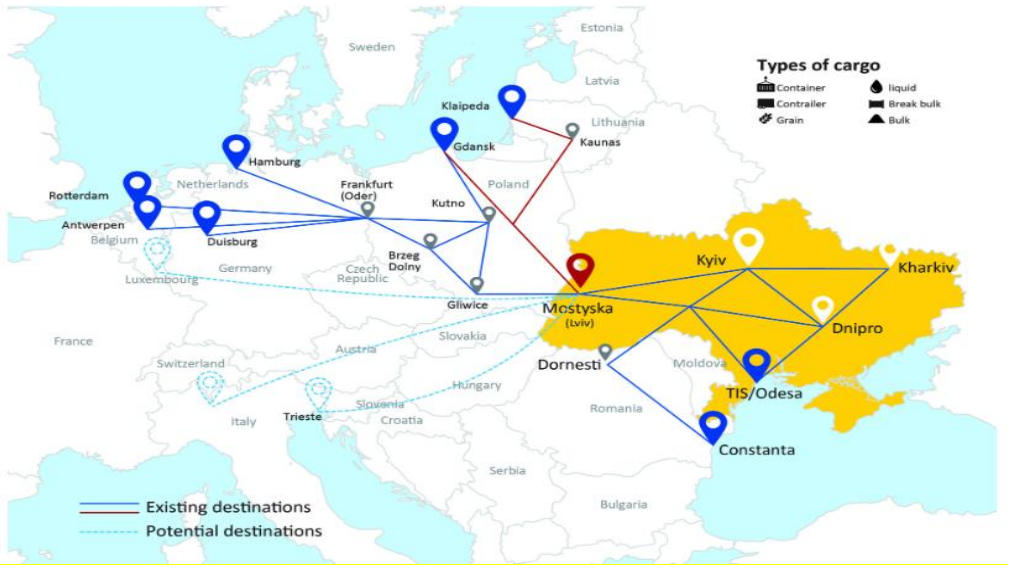

Figure 2: Existing and potential destinations of Mostysk Container Terminal
Source: Mostyska Container Terminal (2023) URL: https://ctm.in.ua/.

Summarizing various studies made it possible to single out the following strategies for choosing the location of similar logistics infrastructure facilities: close to sales markets, close to production, or an intermediate location (Figure 3).

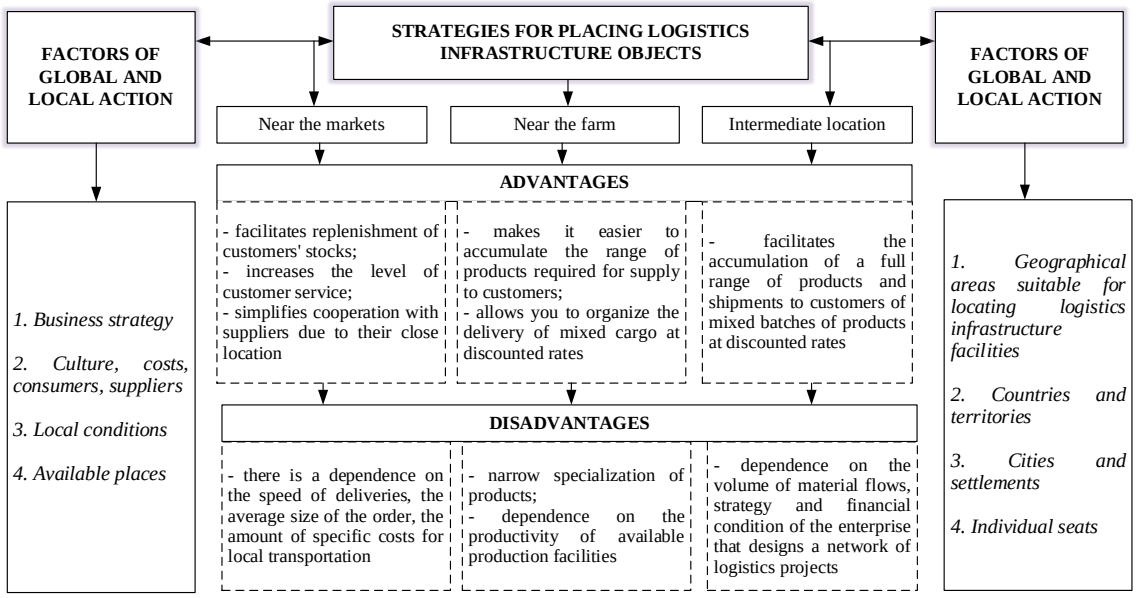

Figure 3: Strategies for placing logistics infrastructure objects
Source: compiled by the authors based on Archetti et al (2021), Baykasoğlu et al (2019), Cempírek et al (2021), He et al (2021), Naumov et al (2020), Zukhruf et al (2022)

The first strategy of locating near sales markets, which involves locating in regions with high customer demand for transport and logistics services, has always been considered economically justified, since the geographic size of the market depends on the average size of orders, the desired speed of deliveries and the amount of specific costs according to the place of transportation. Usually, such objects are in regions with a high level of turnover, however, the recent events that happened in Ukraine due to the full-scale invasion of the Russian Federation on its territory, proved that this method does not consider all possible risks when choosing a location.

The second strategy of location near the production has certain disadvantages, but the expediency of its choice is explained by the increased level of service for the entire range of products supplied the consolidation of product flows of different manufacturers.

The third strategy of intermediate placement is a priority for wholesale companies.

To speed up freight traffic, the choice of a strategy when placing a multimodal terminal should consider such characteristics of delivery routes as the time it takes for vehicles to pass the route, the costs of transportation and handling of various cargoes, the capacity of the network and the terminal. At the same time, it is necessary to consider that some indicators, such as throughput, involve maximization, while others (route travel time, costs) involve minimization. Thus, the problem of choosing a strategy turns into a problem of multi-criteria optimization, which will allow to calculate the approximation of the entire Pareto front, that is, to develop a compromise strategy. Then the choice of strategy, considering that by changing the sign of the function it is always possible to reduce the minimization problem to the problem of maximization, the problem of choosing a strategy when placing a multimodal transport terminal can be written as follows:

$$F_E(\bar{S}) = \langle F_{th}(\bar{S}), F_t(\bar{S}), F_{exp}(\bar{S}), F_{pr}(\bar{S}) \rangle \to max, \quad (1)$$

$$\bar{S} \in Q, \quad (2)$$

where, $F_E(\bar{S})$ – criterion for choosing the optimal strategy for placing a multimodal transport terminal; $F_{th}(\bar{S})$ – a private criterion for maximizing the bandwidth of a

multimodal transport terminal; $F_t(\bar{S})$ – a private criterion for minimizing the time of the route; $F_{exp}(\bar{S})$ – a private criterion for minimizing costs associated with freight traffic; $F_{pr}(\bar{S})$ – a private criterion for maximizing the economic effect from the creation and operation of a multimodal transport terminal; $\bar{S}$ – admissible strategy for placing a multimodal transport terminal; Q – the range (set) of admissible strategies for placing a multimodal transport terminal.

As can be seen from function (1), two criteria imply maximization ($F_{th}(\bar{S}), F_{pr}(\bar{S})$), and others – minimization ($F_t(\bar{S}), F_{exp}(\bar{S})$). Therefore, the process of solving problems (1)-(2) is inevitably connected with expert evaluations of both the criteria themselves and the relationships between them. The conducted survey of experts (28 leading scientists and logistics specialists took part in the survey, the agreement of their opinions according to the concordance coefficient was 0.748) showed that among the selected criteria, the most important is the criterion of maximizing the economic effect from the creation and operation of a multimodal transport terminal ($F_{pr}(\bar{S})$), respectively, other criteria will play the role of additional restrictions. Then problem (1)-(2) can be rewritten in the following form:

$$E(\bar{S}) = \langle F_{pr}(\bar{S}) \rangle \rightarrow max, \quad (3)$$

$$Th(\bar{S}) \geq Th_{min}, \quad (4)$$

$$T(\bar{S}) \leq T_{max}, \quad (5)$$

$$E(\bar{S}) \leq E_{max} \quad (6)$$

$$\bar{S} \in Q, \quad (7)$$

where, $Th(\bar{S})$ – is the freight traffic that can be processed when choosing the $\bar{S}$-strategy; Th_{min} – the minimum necessary freight traffic that can be processed at the multimodal terminal per unit of time; $T(\bar{S})$ – is the time of passage of the cargo delivery route when choosing the strategy $\bar{S}$; T_{max} – the maximum allowable time for passing the cargo delivery route; $E(\bar{S})$ – cargo delivery and handling costs when choosing strategy $\bar{S}$; E_{max} – s the maximum allowable costs for delivery and handling of goods.

The use of model (3)-(7) will allow to determine an effective strategy for placing a multimodal terminal, which will also be Pareto optimal (Mirjalili and Dong, 2019).

This problem stimulates the study of all possible factors that influence the decision-making regarding the location of the multimodal transport terminal, considering global and local factors (Figure 3).

All factors affecting the decision-making regarding the location of the multimodal transport terminal are grouped by the authors into five groups:

Group 1: political and legal (level of political and legislative stability; tax legislation (including rules for the construction of infrastructure facilities); level of investor protection; availability of a free economic zone; subsidies, grants, etc.);

Group 2: economic and social (dynamics of the main macroeconomic indicators; external and internal freight flows, development of scientific, technical, and innovative indicators);

Group 3: natural-geographic and ecological (climate; air temperature, level of development and intensity of use of natural resources; development of the system of state control of environmental protection; proximity to processing and trading enterprises);

4th group: infrastructural (technical and operational characteristics of transport and logistics infrastructure);

5th group: demographic (population and its structure).

In addition, the authors propose to single out the fifth group and take into account the factors of global security, which is caused by the challenges of integrity and security in modern globalism and intercivilizational interaction: social (war, socio-political conflicts, crimes, famine, etc.); natural (decrease or increase in air temperature, precipitation, earthquakes, solar radiation, etc.); man-made (explosions and other unforeseen events; fires, breakdowns of technical systems, etc.).

In addition to the general factors listed above, specific factors that consider the regional aspect should be considered. In the future, the study is aimed at diagnosing the factors of local action for deciding on the placement of a multimodal transport terminal at the regional level. For this purpose, the method of critical analysis of information by the Japanese professor K. Ishikawa - "Fishbone" was used, which made it possible to detail the distribution of factors into subgroups: infrastructural factors, scientific, technical, and innovative factors, economic factors, demographic and security factors (Figure 4).

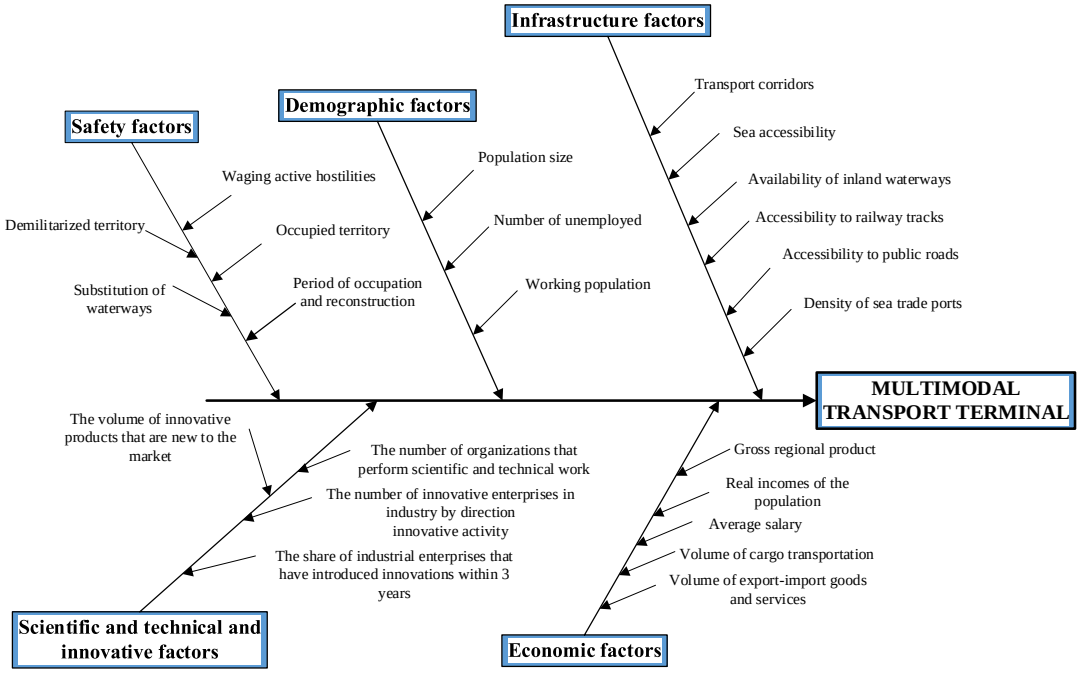

Figure 4: Ishikawa diagram
Source: built by the authors.

When studying the choice of location, it is worth taking into account factors that can be classified as limiting factors: topological and resource limiting factors (localization of available resources for logistics activities; availability of labor, consumers, technical support, etc.), organizational and managerial limiting factors (level qualifications of managers, the use of innovative technologies for the purpose of managing business processes and "automating" management decisions), financial limiting factors (available and effective cost estimation methods and their optimization).

To decide on choosing the most attractive territorial region in Ukraine for the construction of a multimodal transport terminal, the factors of regional direction were analyzed through the prism of calculating the priority risk number (PRN). Based on the results of a survey of leading experts in the field according to such criteria as the significance of the risk, the probability of its occurrence and the probability of detection, it was established that the greatest risk of exposure has 5 criteria from different groups of

factors, and the results of the used method made it possible to conduct an ABC analysis, using which these criteria were divided into three unequal subsets A, B, C (Figure 5).

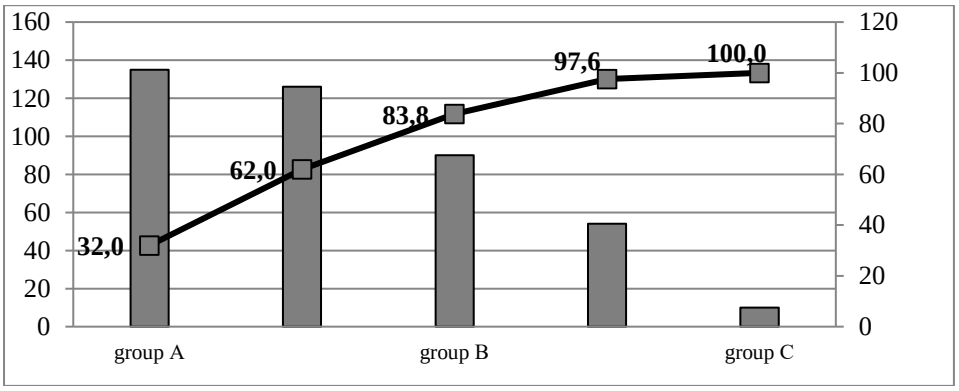

Figure 5: Pareto chart – Lorenzo's curve
Source: constructed by the authors.

The results of the study show that the most significant influence on the choice of the location of the multimodal transport center from a risk perspective has the criteria "conduct of hostilities" from the group of security factors and the criterion "availability of transport corridors" from the group of infrastructural factors. Let's take these criteria as a basis for further research.

In the context of recent geopolitical changes, the destruction of established logistics chains and the integration of the Ukrainian transport system into the European one, the increased flexibility and expanded ability to serve larger volumes of cargo flows due to the formation of a multimodal transport terminal will primarily contribute to the reduction of transport and logistics costs. In turn, this will ensure that territorial communities receive an influx of investments and tax revenues, which will affect their socio-economic situation. That is, the development of the transport sector of Ukraine is of key importance in the reconstruction of transport infrastructure and restoration of economic potential.

International transport corridors passing through the territory of Ukraine play a significant role in the implementation of multimodal transportation, because they are the basis of the development of a sustainable multimodal transport network. The core network covers nine corridors that pass through the EU and are grouped into three general directions: east-west, north-south and diagonal corridors. The following corridors pass through Ukraine: No. 3, 5, 7, 9 of the Trans-European Transport Network (TEN-T). The corridor "Europe - Caucasus - Asia" (TRACECA), which is often called the "Great Silk Road of the 21st century" today received the biggest challenges associated with the operation of the Trans-Caspian transport corridor bypassing Russia due to transit restrictions and the application of sanctions (Table 2).

Table 2: Globalization processes of transformation of international transport corridors and ways of development of transport infrastructure of Ukraine.

International transport corridor	*Advantages*	*Barriers*
Inclusion of Ukrainian logistics routes in the Trans-European Transport Network (TEN-T):	- elimination of existing obstacles during logistics operations;	-

- The North-Baltic Corridor was extended through Lviv and Kyiv to Mariupol; - Baltic-Black Sea - Aegean Corridor extended through Lviv, Chernivtsi (Romania and Moldova) to Odesa - Baltic Sea - Adriatic Sea and Rhine - Danube corridors will pass through Lviv (The EU included Ukrainian et al, 2022)	- attraction of European investments for the modernization of transport infrastructure; - obtaining access to EU assistance tools in the development of the Ukrainian part of the TEN-T network; - development of multimodal transportation; - reduction of logistics costs; - improving the quality of services during the transportation of goods	
corridor Europe - Caucasus - Asia (TRACECA): trade and transport in the regions of the Black Sea Basin, South Caucasus and Central Asia.	strengthening regional integration along the Middle Corridor, a fast-growing land and sea freight route from China to Europe that aims to be a viable alternative to the long-established northern route through Russia.	- lack of carrying capacity of the transport infrastructure of the participating countries: Azerbaijan, Georgia, Kazakhstan, and Turkey; - the absence of the possibility of involving the deep-sea ports of the Black Sea due to mining; - an increase in the cost of delivery, due to the crossing of several borders on the route from Asia to Europe along the middle corridor, compared to the northern Russian corridor.

Source: systematized by the authors

Then, considering the above, the effect of creating a multimodal transport terminal can be represented by a function of the following form:

$$E = f(F_s, S, GS) \rightarrow max, \quad (8)$$

where, F_s – is a set of system factors that reflect the proximity to the transport corridor, the development and condition of the transport infrastructure, the volume of export-import goods and services, proximity to the border with the EU; S – the chosen strategy for creating a multimodal transport terminal (close to sales markets / close to production / intermediate location); GS – is the security level of the location of the multimodal transport terminal (socio-economic stability in the region, military actions, etc.).

In the conditions of the need to restore territories that were in the war zone or under occupation, the following factors should be considered when choosing the location of the terminal:

1) the state of the transport network, i.e., whether it is in a stationary state or whether a part of it or is not in a functional state as a whole;

2) the conditions for the passage of routes through the terminal, i.e., the routes must provide bypassing of non-functioning or prohibited sections of the transport network.

In the context of the integration of the Ukrainian transport system into the European one (Ukraine on the way to the EU: realities and prospects, 2022) and the reconstruction of the infrastructure of Ukraine, the question of determining the optimal technologies for the delivery of goods and regulatory and legal support is particularly relevant, namely:

1) the accession of Ukraine to the EU Common Aviation Area (CAA);

2) integration of the transport and logistics infrastructure of Ukraine into the European TEN-T;

3) to legally ensure Ukraine's participation in TEN-T, the laws "On Accession to the Agreement on the Development of TRACEKA Multimodal Transportation" and "On Multimodal Transportation" were adopted.

The latter envisages the implementation of the EU Directive on establishing common rules for certain types of transportation of goods between member states. Multimodal transportation makes it possible to increase the volume of cargo transportation with the participation of national transport companies, to reduce the cost of logistics, to reorient part of the cargo to other modes of transport, to integrate the transport infrastructure of Ukraine not only into the European, but also into the world. Participants of multimodal transportation received the right to carry out cargo transportation based on the conclusion of a single contract for all stages of transportation, regardless of the change in modes of transport (The EU included Ukrainian logistics routes in the Trans-European transport network, 2022).

4) Ukraine in May 2022. developed the EU-Ukraine Roads of Solidarity action plan, and on June 29 signed the Agreement on road freight transport with the EU. This provided certain privileges the need for Ukrainian carriers to obtain appropriate permits for bilateral and transit transportation to EU states is abolished; it is possible to avoid stopping the export of Ukrainian products through automobile checkpoints; measures to simplify the recognition of driver's licenses are foreseen. From now on, Ukraine and the EU exempt holders of driver's licenses issued by one of the parties from the requirement to have an international driver's license.

5) From August 1, 2022. e- goods and transport invoices (electronic waybills) were to become mandatory for all transport operations in Ukraine.

6) Convention on the joint transit procedure from October 1, 2022.

Thanks to close cooperation at the interstate level and the implementation of international norms and standards, the ultimate goals of the indicated development paths are the formation of a road map for the reconstruction of Ukraine's transport infrastructure.

Designing the creation of a multimodal transport terminal, as part of the transport infrastructure of Ukraine, should provide for the determination of the mechanism of its financing. Ukraine, as a state that will restore the economy and social sphere after the end of military aggression, will face a huge shortage of financial resources. This necessitates the involvement of private investors in the implementation of infrastructure projects. As world practice shows, such a mechanism is a private-public partnership, which is now "an innovative way of procuring public infrastructure projects over the last two decades" (Baykasoğlu et al, 2019).

The Public-Private Partnership (PPP) mechanism has significant advantages over budget financing, among which the following should be noted: (1) improvement of the quality of services for the population and business, reduction of the burden on the state budget and optimization of budget expenditures for the provision of services, improvement of the efficiency of management of state-owned objects; (2) the possibility of carrying out both short-term and long-term development planning, since the PPP mechanism has a long-term nature with clearly defined time frames. The effectiveness of PPPs for financing infrastructure facilities, the variety of institutional conditions for its implementation led to the emergence of various types of concession contracts (BOT (Build - Operate - Transfer), BTO (Build - Transfer – Operate), BOO (Build - Own - Operate), BOOT (Build - Own - Operate - Transfer), BBO (Buy - Build - Operate)).

When choosing a specific PPP model, it is necessary to consider the system of factors (constraints), the implementation of which will ensure the creation, effective management, and use of the infrastructure object. Such a system of factors should include the following factors:

(1) reconciliation of social and economic efficiency;

(2) optimal ratio of "interests" of the state and private investors;

(3) distribution of risks between partners;

(4) terms of creation of the object, its operation, and its transfer to the state.

Then, considering the above and factors (1)-(4), the assessment of the expected effect of using the PPP mechanism to create a multimodal terminal can be presented as a solution to the following problem:

$$f(EF, ES, t) \to max, \quad (9)$$

$$EF = \sum EF_{St} + \sum EF_{PI}, \quad (10)$$

$$ES = \sum ES_{St} + \sum ES_{PI}, \quad (11)$$

$$\sum EF_{PI} > 0, \sum EF_{St} > 0, \quad (12)$$

$$\sum ES_{St} \geq 0, \sum ES_{St} \geq 0, \quad (13)$$

where, EF, ES – economic and social effects that will be obtained from the use of the concession agreement when creating a multimodal transport terminal; $\sum EF_{St}$, $\sum EF_{PI}$ – the total economic effect of the creation of a multimodal transport terminal for the state and private investors, respectively; $\sum ES_{St}$, $\sum ES_{PI}$ – the total social effect of the creation of a multimodal transport terminal for the state and private investors, respectively; t ($t = \overline{0, T}$) – years of the implementation of the concession agreement.

Problem (9)-(13) must be supplemented with the following restrictions:

1) the obligation to ensure the necessary turnover of goods:

$$V_{CT}^{pl}(t) \geq N_{CT}^{f}(t), \quad (14)$$

where, $V_{CT}^{pl}(t)$ – the planned (forecast) volume of cargo turnover that can be processed in the multimodal transport terminal in year t; $N_{CT}^{f}(t)$ – forecast needs for cargo processing in the year t;

2) profit making by private investors:

$$\sum_{t=t_p}^{T} P'_{pl}(t) \geq \sum_{t=0}^{t_e} KI(t), \quad (15)$$

$$\frac{\sum_{t=t_p}^{T} P'_{pl}(t)}{\sum_{t=0}^{t_e} KI(t)} \geq N_P, \quad (16)$$

where, t_e – year of end of the concession facility financing; t_p – the year from which the concessionaires will profit from the operation of the facility; $P'_{pl}(t)$ – planned profit that a private investor will receive in year t; $KI(t)$ – capital investments provided for by the concession agreement; N_P – rate of return accepted by private investors for capital investments in infrastructure facilities;

3) acceptable level of investment risks in the creation of a multimodal transport terminal - the payback period of capital investments in its creation should not exceed the limit value:

$$h \leq h_l, \quad (17)$$

where, h - the period during which the number of profits will be equal to or exceed the amount of capital investments of private investors (payback period):

$$\sum_{t=t_p}^{h} P'_{pl}(t) \geq \sum_{t=0}^{t_e} KI(t), \quad (18)$$

where, h_l – the limit value of the payback period.

The implementation of model (9)-(18) will allow to choose the most effective PPP mechanism for financing, the implementation of which will allow both to ensure the creation of a multimodal terminal capable of ensuring the necessary turnover of goods, and to consider the economic and social interests of the state and private investors.

5. Conclusions and further research

The study was devoted to multimodal transport terminals, which are key nodes in the integration processes into global logistics networks and the EU Single Market in the conditions of socio-economic recovery of Ukraine. The relevance of the study is confirmed by the fact that in conditions of high instability, readiness for socio-economic recovery of Ukraine is accompanied by strategic decisions and projects in many areas: infrastructure and transport, financing, telecommunication networks, ecology and environment, etc. However, the dynamic nature of the restoration and restructuring of transport infrastructure requires the parallel formation of multimodal transport terminals. This is due to the growing demand for multimodal transportation and the creation of additional transshipment capacities. The role of multimodal transport terminals is shown precisely during the period of restoration of the destroyed infrastructure of Ukraine after the end of the "hot phase" of the war. Attention was focused on the fact that transport terminals are a critical element in the process of forming supply chains when carrying out multimodal transportation in international and domestic traffic. The advantages and disadvantages of cargo delivery schemes were highlighted and the actual capacity of multimodal transport terminals located near the borders of Ukraine was given.

It was proven that the reorientation of cargo flows in international transport corridors and significant damage to transport infrastructure require changes in scientific and practical approaches to designing the location of multimodal transport terminals. An approach to choosing a strategy for the location of a multimodal terminal through multi-criteria optimization was substantiated, which allowed developing a compromise strategy. For this purpose, the authors proposed two economic and mathematical models: a model for determining the strategy for choosing the location of a multimodal transport terminal to optimize cargo flows and a model for assessing the expected effect of using the public-private partnership mechanism in creating a multimodal transport terminal. The proposed models considered five groups of factors that were identified using the Ishikawa Diagram toolkit. Also, based on the Pareto principle, the criteria that had the most significant impact on the choice of location for a multimodal transport terminal were identified. These were two criteria: the conduct of hostilities and the availability of transport corridors.

It was substantiated that the design of a multimodal transport terminal, as part of Ukraine's transport infrastructure, should include determining the mechanism for its financing. Further research should include modelling scenarios for the development of multimodal infrastructure in post-war reconstruction, taking into account security, demographic, and environmental risks. In addition, it is advisable to study adaptive models of financing the creation or reconstruction of multimodal transport terminals in conditions of acute shortage of funds.

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