

Using cluster analysis of the transport and logistics infrastructure of Ukraine to form regional development strategies

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Abstract. The war caused uneven and asymmetric changes in the transport and logistics infrastructure of Ukraine, which necessitated the study of the level of its development in individual regions, with their subsequent grouping and development of differentiated strategies for stabilisation and further development of logistics during the period of martial law and post-war economic recovery. The aim of the article was to develop methodological approaches to justifying and developing strategies for stabilisation and development of the transport and logistics system of Ukraine during the war and post-war period, taking into account the asymmetric and uneven impact of the war on the regions. To achieve the goal, the cluster analysis method was chosen to group the regions of Ukraine by the potential/functioning of their transport and logistics infrastructure, the level of development of which was assessed as very high, high, high, medium and low. As a result of the clustering and grouping of regions of Ukraine by indicators of “number of enterprises” (characterises logistics potential), “volume of implementation of transport and logistics infrastructure enterprises” (functioning of logistics), five differentiated strategies were proposed for the period of martial law and in the post-war period, which cover the following aspects of the strategic development of logistics in the regions of Ukraine: infrastructure, logistics and operational, security, innovation and technology, integration (international), economic, spatial and regional and socio-humanitarian. The key strategic directions for the development of transport and logistics infrastructure of Ukraine in war conditions include the reorientation of logistics flows to the western regions, decentralisation of logistics processes and ensuring flexibility of routes in accordance with the criteria of safety, efficiency and effectiveness. In the post-war period, the priorities for the restoration and development of the transport and logistics system were identified as integration into the European transport space, the development of modern logistics hubs, and the implementation of intelligent logistics solutions. The practical value of the study is based on the fact that the comprehensive implementation of the proposed strategies will ensure the stability of logistics systems during the war period and create the prerequisites for effective post-war restoration and integration of Ukraine into global transport and logistics networks

Keywords: regional logistics infrastructure; logistics; smart logistics; clustering; strategic approach

● INTRODUCTION

Since the beginning of the full-scale Russian invasion, the logistics infrastructure of Ukraine has undergone significant transformation due to its destruction, the cessation or reduction of the activities of transport and logistics enterprises, the partial occupation of Ukrainian territories, and the shift of the centre of gravity of economic flows from the east to the west of the country. This has led to significant changes in the internal regional structure of logistics

in Ukraine, which has updated the scientific search for new ways to adapt domestic business to changes in the logistical accessibility of individual regions, as well as the development of regional strategies for the development of logistics infrastructure in wartime and during the post-war revival of the Ukrainian economy.

Changes in the logistics landscape of Ukraine have been studied by many researchers who analysed various

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aspects of the functioning of logistics chains in wartime. Thus, Y. Krykavskyy *et al.* (2023), using the graphic visualisation method – Futures Wheel, identified a group of consequences of the Russian-Ukrainian war – “destruction of logistics infrastructure” and identified within this group the effects of the wave effect, such as: attacks and blockades of sea and river ports, use of alternative export and import routes, increased use of Danube ports, closure of airways, fuel shortage as a result of the destruction of oil depots, increased transport costs, shortage of vehicles, destruction of roads/railways/ports, delays in deliveries, restrictions on transport flows at customs.

In line with these findings, D. Steblak & V. Lyssy (2022) emphasised that “the events of February 24, 2022, changed not only the social sphere of the population’s life, but also significantly affected international economic relations, which is especially noticeable in the field of international logistics”, emphasising the profound transformation of Ukraine’s logistics environment under the pressure of wartime.

L. Lebedeva & D. Shkuropadska (2024) identified, in addition to the above, such consequences of the war as a decrease in the level of commodity stocks due to increased risks of losses, difficulties with procurement and a shortage of warehouses due to their destruction; overloading of European infrastructure due to different track widths and low equipment productivity. The authors propose to increase the sustainability of transport and logistics systems of Ukraine through the implementation of infrastructure, technological, organisational and economic measures. In terms of organisational measures, special attention is paid to strategic planning for the development of transport and logistics systems, taking into account possible risks and scenarios of crisis situations.

According to Ya. Korniiiko & S. Karpeliuk (2026) the impact of the war on the transport and logistics infrastructure was manifested in the formation of a multi-channel multimodal system, where the ports of the Odessa region, the Danube cluster and land routes with the European Union play the main role. The stability of logistics chains in the conditions of the war period began to be determined by the ability to quickly redistribute transportation volumes between routes and modes of transport, which necessitates the need for cluster analysis of transport corridors. The logic of the functioning of domestic logistics has changed priorities: from tariffs to taking into account risks, infrastructure availability, queues, inspections and security factors.

I. Kyrchata *et al.* (2024) identified strategic directions for the restoration and development of Ukraine’s transport infrastructure based on a project approach. Y. Rudyk *et al.* (2023) proposed a set of measures to stabilise domestic logistics in terms of ensuring the functioning of grain supply chains, including the construction of terminal complexes on the border with the EU; development of pipeline transport of vegetable oils, increasing the fleet of hopper wagons and trucks, allocation of separate railway routes to EU ports, development of alternative export corridors through the Danube and European ports.

Summarising the publications of Ukrainian scientists on the impact of the war on the transport and logistics infrastructure and the prospects for its stabilisation/restoration, it was noted that most authors characterise the

impact of the war as uneven, asymmetric and multidimensional, noting its numerous negative consequences. At the same time, the authors focus their attention on measures, models, mechanisms that directs on infrastructural, technological, organisational and economic transformations in the near and long term. Scientists focus particular attention on the strategic aspects of stabilisation and restoration of the logistics system of Ukraine. At the same time, scientific works lack a methodological approach to developing strategies for the development of the transport and logistics system of Ukraine, taking into account the uneven negative impact of the war on the regions: different levels of infrastructure destruction, different accessibility of ports, corridors and multimodal nodes, differences in throughput and institutional conditions, different intensity of risks and logistical constraints and specific needs of individual industry regions. The aim of the article was to advance methodological approaches for substantiating and designing strategies aimed at the stabilisation and development of Ukraine’s transport and logistics system during the wartime and post-war periods, considering the asymmetric and uneven effects of the war across regions.

● MATERIALS AND METHODS

The study was conducted according to the following sequence. At the first stage, the rationale for and the structure of the cluster analysis of the transport and logistics infrastructure (TLI) of Ukraine’s regions were substantiated and defined. At the second stage, the empirical analysis was carried out, involving the clustering of 25 regions of Ukraine based on the selected indicators: “number of enterprises” and “sales volume of TLI enterprises”. For the cluster analysis, a sample of 25 regions of Ukraine was formed (excluding the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, parts of the temporarily occupied territories of Donetsk and Luhansk regions, as well as territories temporarily occupied by the Russian Federation and areas where hostilities are or have been ongoing) (State Statistics Service of Ukraine, n.d.). Luhansk, Donetsk, and Kherson regions were included in the analysis as administrative regions of Ukraine based on available official statistical data and estimates, which allowed to reflect the asymmetric impact of the war on the transport and logistics infrastructure of the regions. The clustering procedure (k-means) was conducted based on the indicators “number of enterprises” and “sales volume” in freight road transport, freight rail transport, and warehousing using IBM SPSS Statistics.

At the third stage, a methodological approach to the development of differentiated strategies for the stabilisation and advancement of Ukrainian regions in both wartime and post-war periods was elaborated. To assess the asymmetric development of regional transport and logistics infrastructure, cluster analysis was employed as one of the most widely used methods in similar studies (Dmytriieva, 2020). The clustering procedure (k-means), complemented by the Nearest Neighbour Analysis method, was performed using the IBM SPSS Statistics software package. For the clustering of regional transport and logistics systems, the most relevant indicators characterising their condition were selected – namely, indicators of resource potential and market activity in the logistics sector, including:

- the number of active enterprises by mode of transport;
- the number of operating warehousing enterprises (warehouse complexes, logistics centres, distribution centres, logistics hubs, etc.);
- sales volume by mode of transport;
- sales volume of warehousing enterprises.

The “number of enterprises” indicator reflects the state of the resource base (logistics potential), while the “sales volume” indicator captures the level of logistics activity (functional performance). Both indicators are representative, statistically available, and enable interregional comparisons across key elements of the logistics system – particularly the most significant modes of transport in Ukraine (freight road and freight rail transport) as well as the warehousing sector. This justifies their selection for the cluster analysis of regional transport and logistics systems. The objective of the cluster analysis is to group Ukrainian regions according to the state and current performance of their transport and logistics infrastructure, which can be characterised as exhibiting: very high, high, above-average, medium, or low levels of development. The study covered the period 2012–2024, which allowed comparing the state of regional transport and logistics infrastructure before and during military transformations. The clustering of regions covered the period 2024. Statistical data were obtained from official national statistical sources and processed in a comparable regional format (State Statistics Service of Ukraine, n.d.).

In addition to freight road and rail transport, the analysis also included freight water transport due to its strategic importance for export logistics, foreign trade flows, and the functioning of port infrastructure during wartime. The inclusion of water transport indicators was justified by the significant regional differentiation in access to maritime logistics infrastructure and the changing role of alternative transport corridors under wartime conditions. The number of clusters was determined based on the interpretability of results, the minimisation of intra-group variance, and the maximisation of inter-group differences achieved through the k-means clustering procedure. The clustering outcomes were additionally verified using the Nearest Neighbour Analysis method in order to ensure the stability and consistency of the identified regional groups. To support the development of differentiated stabilisation and development strategies, integration matrices were constructed on the basis of two dimensions: the level of logistics infrastructure potential and the level of logistics activity. Regions were assigned to corresponding groups according to their relative positions within the cluster structure and the calculated indicator values. This approach enabled the identification of regions with similar logistical characteristics, infrastructural constraints, and development capacities, thereby ensuring the transparency and reproducibility of the analytical results.

● RESULTS

The transport and logistics infrastructure of a country constitutes an integrated system of transport routes, modes of

transport, and communication, warehousing, and auxiliary facilities that ensure the implementation of logistics processes and the functioning of supply chains in both national and global markets. A systematic review of 28 articles conducted by A.M. Varghese & R.P. Pradhan (2025) generally confirmed the causal relationship between “transport infrastructure” and “economic growth” across countries, underscoring the significance and critical role of transport and logistics infrastructure even in peacetime. This is also emphasised in their works by scientists B.B. Badassa *et al.* (2020). A. Konno *et al.* (2021) analyse the impact of road infrastructure on economic productivity on a global scale; the spatial effect is taken into account in the regional production function. In crisis situations, such as war, the importance of transport and logistics infrastructure increases manifold. Its condition directly determines the resilience of a country, its ability to ensure continuity of supply, sustain economic activity, respond promptly to risks, and guarantee the functioning of critical sectors under large-scale threats.

The strategic potential of transport and logistics infrastructure lies in its capacity to influence countries’ integration into the global transport system and international trade, as well as their investment climate, defence capability, and national security (Stehnei *et al.*, 2026). As outlined in the Transport Strategy of Ukraine up to 2030, the modern development of Ukraine’s transport system should take into account the need to adapt to EU standards, technical regulations, and governance principles, as well as the importance of innovation and advanced technologies in shaping a more efficient model for managing the development of the national transport network (Order of the Cabinet of Ministers of Ukraine No. 430-r, 2018).

Ukraine’s transport and logistics infrastructure has experienced extensive destruction, asymmetric changes, and structural transformations that have adversely affected the national economy. At the same time, it has demonstrated resilience and continues to function and fulfil its essential tasks. Ensuring its continued operation during wartime and its recovery in the post-war period depends on the implementation of effective strategies aimed at leveraging opportunities and mitigating negative ripple effects (Krykavskyy *et al.*, 2023). The impact of the war on significant changes in the structure of transportation by various modes of transport is investigated by D. Steblak & V. Lysyy (2022). Since 2022, sales volumes across certain components of Ukraine’s transport and logistics infrastructure have declined unevenly. The railway freight sector and aviation transport have proven particularly vulnerable, primarily due to the closure of Ukraine’s airspace. At the same time, the dynamics of sales volumes in freight road transport, maritime freight transport, and the warehousing sector have generally remained positive (Fig. 1).

Significant shifts in the functioning of transport infrastructure have occurred across all regions of Ukraine, but individual regions have been affected by military actions to varying degrees. One of the negative effects of the war is the regional unevenness of the current state of transport and logistics infrastructure (Fig. 2).

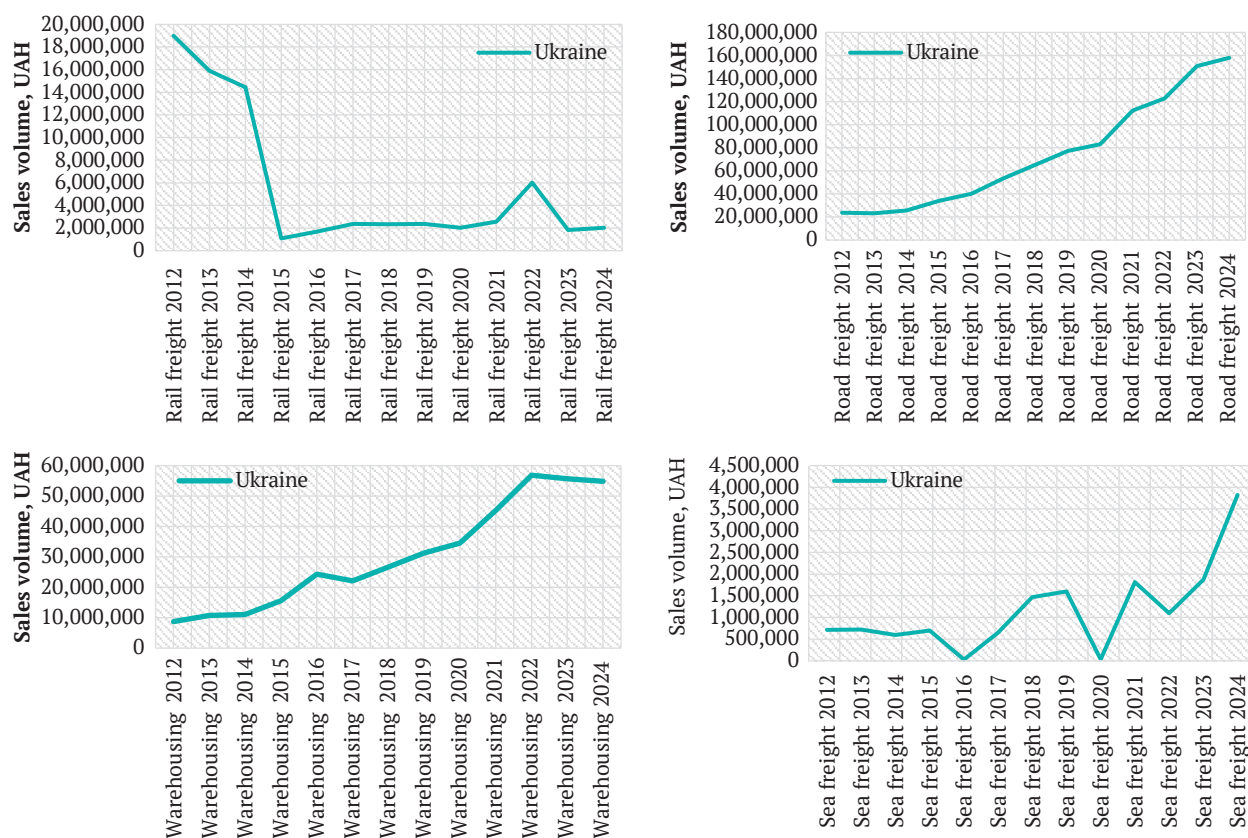


Figure 1. Dynamics of sales volumes across TLI components

Source: developed by the author based on State Statistics Service of Ukraine (n.d.), S. Smerichevska *et al.* (2023)

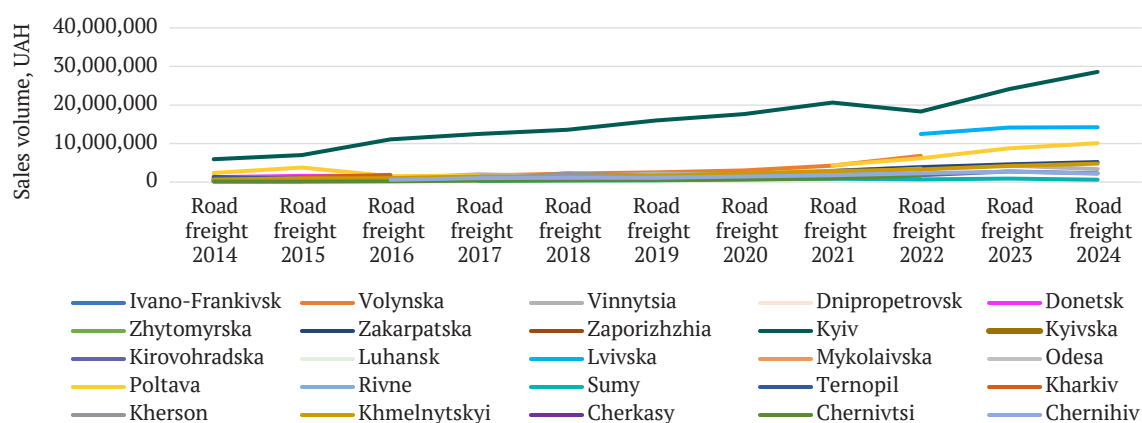


Figure 2. Uneven development of freight road transport in the regions of Ukraine

Source: developed by the author based on State Statistics Service of Ukraine (n.d.)

M. Stehnei *et al.* (2026) noted an intensification of intersectoral asymmetries in the use of transport and logistics potential in Ukraine, which significantly complicates the implementation of competitive and internationally oriented transport operations, reduces the sector's investment attractiveness, and limits opportunities for multimodal transportation. An analysis of the structure of Ukraine's transport and logistics system across regions

revealed significant disparities in the number of operating transport enterprises (by mode of transport) and warehousing facilities. Considerable differences are also observed in logistics activity, reflected by the indicator "sales volume of transport and logistics infrastructure enterprises (goods and services)". The selection of the indicators "number of operating transport and warehousing enterprises" and "sales volume of transport and logistics

infrastructure enterprises (goods and services)” is justified by their importance and analytical interpretability. Clustering Ukrainian regions based on these two indicators

makes it possible to identify leading regions as well as regions with high or low levels of transport and logistics infrastructure development (Table 1).

Table 1. Justification of key indicators for clustering the transport and logistics system of Ukrainian region

Indicator	What it measures	Why it is important for TLI analysis	What conclusions it allows
Number of operating transport and warehousing enterprises	Level of infrastructure provision and availability of logistics capacity in the region	Reflects the scale of logistics infrastructure, availability of transport services, level of competition, and capacity to handle freight flows	Identify logistics density; assess competition level; detect regions with shortages or excess capacity; evaluate investment attractiveness
Sales volume of transport and logistics infrastructure enterprises (goods and services)	Actual economic activity of enterprises, their market participation, and demand for logistics services	Indicator of logistics activity; shows real contribution to the economy and intensity of logistics operations	Identify economically active regions; assess sector productivity; detect regions with high demand; compare enterprise efficiency
Regional logistics activity (integrated combination of the two indicators)	Ratio between the number of enterprises and their economic performance	Enables assessment of efficiency of infrastructure use, not only its availability	Identify leading regions, regions with development potential, and problem areas with low efficiency

Source: compiled by the author of this study according to The Strategy of Economic Security of Ukraine for the Period Up to 2025 (2021)

The use of these indicators for the main land transport modes (freight road and rail transport) and warehousing enterprises within the cluster analysis of Ukrainian regions allows for the assessment of both the potential of transport and logistics infrastructure (number of enterprises) and actual logistics activity (sales volume). This makes it possible to obtain a realistic picture of the development of regional transport and logistics systems, identify imbalances, and

determine strategic priorities for the development of key components of regional TLI during wartime and the post-war period. As a result of the cluster analysis using the k-means method, five clusters of Ukrainian regions were identified based on the “number of enterprises” indicator, which significantly differ in the level of entrepreneurial activity in the transport and logistics infrastructure sector (freight transport and warehousing) (Tables 2-3).

Table 2. Cluster centres (units) based on the indicator “number of enterprises” in freight road transport, freight rail transport, and warehousing

Final cluster centres	Cluster				
	1	2	3	4	5
Freight road transport	1,062	449	236	588	85
Freight rail transport	68	9	3	10	0
Warehousing	231	54	31	107	13

Source: developed by the author

Table 3. Number of regions in each cluster based on the indicator “number of enterprises” in freight road transport, freight rail transport, and warehousing

Number of cases in each cluster		
Cluster	1	1
	2	3
	3	11
	4	2
	5	8
Valid		25
Missing		0

Source: developed by the author

Cluster 1 (highly developed centre). This cluster includes only the city of Kyiv, indicating its absolute leadership in terms of the number of operating enterprises. The values of indicators in this cluster significantly exceed others, confirming Kyiv’s role as the key logistics and economic hub of the country.

Cluster 2 (high level of development). Includes three regions (in particular, Lviv, Odesa, and Volyn regions). This cluster is characterised by a high concentration of enterprises, especially in road transport and warehousing. These

regions benefit from advantageous geographical locations and active foreign economic relations.

Cluster 3 (medium level of development). The largest cluster (11 regions), covering most regions of Ukraine. It is characterised by average indicator values across all activities, indicating relatively balanced but not maximally efficient development of the transport and logistics sector.

Cluster 4 (above-average level). Includes two regions (in particular, Dnipropetrovsk and Kyiv regions), which demonstrate elevated indicators but lag behind the leaders.

These regions are characterised by a developed industrial base and significant transportation volumes.

Cluster 5 (low level of development). unites eight regions with the lowest values of enterprise numbers across all analysed activities. This cluster includes regions significantly affected by military actions or those with limited economic potential.

Thus, a significant differentiation of Ukrainian regions in terms of the level of logistics activity development is observed. The greatest influence on cluster formation is exerted by road transport, as evidenced by the highest

F-value (Table 4). A clear centre of economic activity (Kyiv) and a group of lagging regions can be identified. Most regions are at a medium level of development, indicating potential for growth. The clustering results confirm the spatial unevenness of the development of Ukraine's transport and logistics system. As a result of clustering Ukrainian regions using the k-means method based on the indicator "sales volumes" in freight transportation by road and rail, as well as in the warehousing sector, five clusters were identified, characterised by significant differences in the level of economic activity (Tables 5-6).

Table 4. Results of the analysis of variance (ANOVA)

based on the indicator "number of enterprises" in freight road transport, freight rail transport, and warehousing

ANOVA	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Freight road transport	302,377.984	4	2,363.455	20	127.939	<0.001
Freight rail transport	1,068.110	4	21.246	20	50.273	<0.001
Warehousing	13,152.740	4	506.984	20	25.943	<0.001

Source: developed by the author

Table 5. Cluster centres (UAH) of each cluster by the indicator "sales volume" of freight road and rail transport and warehousing

Final cluster centres	Cluster				
	1	2	3	4	5
Freight road transport	162,422.3	28,595,728.9	3,557,962.1	0.0	11,683,484.6
Freight rail transport	5,584.7	0.0	0.0	295,248.7	28,226.8
Warehousing	540,155.8	17,987,497.5	1,248,286.8	11,554,508.4	4,102,338.7

Source: developed by the author

Table 6. Number of regions in each cluster by the indicator "sales volume" of freight road and rail transport and warehousing

Number of cases in each cluster		
Cluster	1	13
	2	1
	3	7
	4	1
	5	3
Valid		25
Missing		0

Source: developed by the author

Cluster 1 (low level of sales volumes). The largest cluster (13 regions), which includes regions with low sales volumes across all types of activities. These regions are characterised by limited economic activity in the transport and logistics sector, which may be due to weak infrastructure or the impact of external factors (in particular, military actions).

Cluster 2 (maximum level – leader). Includes only the city of Kyiv, which demonstrates the highest sales volumes, especially in road transport and warehousing. This confirms the dominant role of the capital as the key economic and logistics centre of the country.

Cluster 3 (medium level of development). Includes 7 regions with moderate sales volumes. This cluster is characterised by relatively stable development, but without significant dominance in any particular mode of transport.

Cluster 4 (specialised cluster). Represented by a single region (Dnipropetrovsk region), which stands out due

to high sales volumes in rail transport and warehousing, indicating its industrial specialisation and important role in freight transportation.

Cluster 5 (high level of sales volumes). Includes 3 regions (in particular, Kyiv, Lviv, and Poltava regions), which are characterised by significant sales volumes, especially in road transport and logistics. These are regions with well-developed transport infrastructure and advantageous geographical location.

Thus, a high degree of uneven distribution of sales volumes across the regions of Ukraine has been identified. Clear poles of economic growth can be distinguished – namely, the city of Kyiv and certain industrial regions. The greatest influence on clustering (as in the case of the "number of enterprises" indicator) is exerted by the road transport indicator, as confirmed by the highest F-value (Table 7).

Table 7. Results of the analysis of variance (ANOVA)
based on the indicator “sales volumes” in freight road transport, freight rail transport, and warehousing

ANOVA	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Freight road transport	246,847,405,259,503.970	4	1,034,101,439,217.838	20	238.707	<0.001
Freight rail transport	20,444,039,661.624	4	482,300,229.704	20	42.389	<0.001
Warehousing	97,373,169,825,631.500	4	2,040,049,384,909.675	20	47.731	<0.001

Source: developed by the author

A significant share of regions belongs to the group with low sales volumes, indicating the need to stimulate their development. The formation of distinct clusters is determined by both the economic specialisation of regions and their geographical location and infrastructural capacity. As a result of clustering 25 regions

of Ukraine using the k-means method based on the indicators “number of enterprises” and “sales volumes” in water transport, three clusters were identified, which significantly differ in the level of development of enterprises in the maritime and river transport sectors (Tables 8-11).

Table 8. Cluster centres (units) of each cluster based on the indicator “number of enterprises” in freight water transport

Final cluster centres	Cluster		
	1	2	3
Sea freight transport	0	9	36
Freight river transport	0	14	3

Source: developed by the author

Table 9. Number of regions in each cluster based on the indicator “number of enterprises” in freight water transport

Number of cases in each cluster		
Cluster	1	23
	2	1
	3	1
Valid		25
Missing		0

Source: developed by the author

Table 10. Number of regions in each cluster by the indicator “sales volume” of cargo water transport

Final cluster centres	Cluster		
	1	2	3
Sea freight transport	0.0	338,880.8	3,514,536.6
Freight river transport	0.0	120,899.9	0.0

Source: developed by the author

Table 11. Cluster centres (units) of each cluster by the indicator “sales volume” of cargo water transport

Number of cases in each cluster		
Cluster	1	23
	2	1
	3	1
Valid		25
Missing		0

Source: developed by the author

Cluster 1 is the largest and includes 23 regions. It is characterised by minimal or zero values of the indicators, indicating weak development or the actual absence of water transport enterprises. This suggests that for most regions of Ukraine, water transport is not a significant segment of economic activity, which may be explained by geographical, infrastructural, and economic factors.

Cluster 2 is represented by only one region – the city of Kyiv – which is characterised by a moderate level of development of river transport enterprises and limited activity in maritime transport. This highlights the specific role of the capital as a logistics and transport hub, where river transport has a limited but present significance.

Cluster 3 also includes a single region – Odesa region – which significantly differs from others due to high indicators of maritime transport enterprises. This confirms its key role as the main maritime transport centre of Ukraine and indicates a high concentration of relevant infrastructure and business activity.

The distances between cluster centres are substantial, confirming a clear differentiation of regions according to the analysed indicators. The results of the analysis of variance (ANOVA) demonstrate statistically significant differences between clusters for both variables (maritime and river transport), confirming the validity of the clustering (Table 12).

Table 12. Results of the analysis of variance (ANOVA)
based on the indicator “number of enterprises” in maritime and river freight transport

ANOVA	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Freight road transport	633.711	2	0.510	22	1,242.860	<0.001
Freight rail transport	90.741	2	0.431	22	210.619	<0.001

Source: developed by the author

The obtained results indicate a high level of territorial asymmetry in the development of water transport enterprises in Ukraine, where individual leading regions dominate against the background of the majority of territories with a low level of development in this type of economic activity. This underscores the need to formulate a differentiated regional policy aimed at developing transport infrastructure and stimulating entrepreneurship in the field of water transportation. The results of the cluster analysis are considered to be of practical significance for the

formation of an effective regional logistics policy, which should include the identification of investment priorities in transport infrastructure, the development of strategies for balancing regional development, and the improvement of SMART logistics systems. The integration of the results of cluster analysis of Ukrainian regions based on the indicators “number of enterprises” and “sales volumes” for the main land freight transport modes (road and rail) and warehousing provides grounds for distinguishing 10 groups of regions (Table 13).

Table 13. Matrix of integration of cluster analysis results
based on the indicators “number of enterprises” and “sales volumes” of transport
and logistics infrastructure enterprises (freight road transport, freight rail transport, warehousing)

Clusters	C1(S) (Low Sales Volume)	C2 (S) (Maximum Level)	C3 (S) (Medium Development Level)	C4 (S) (Specialised Cluster)	C5 (S) (High Sales Volume)
C1(N) (Highly Developed Centre)	-	Kyiv	-	-	-
C2 (N) (High Level of Development)	Volyn, Odesa	-	-	-	Lviv
C3 (N) (Medium Level of Development)	Ivano-Frankivsk, Zaporizhzhia, Rivne, Kharkiv, Cherkasy	-	Vinnytsia, Zakarpattia, Kirovohrad, Mykolaiv, Khmelnitskyi	-	Poltava
C4 (N) (Above Average Level)	-	-	-	Dnipropetrovsk	Kyiv
C5 (N) (Low Level of Development)	Zhytomyr, Luhansk, Sumy, Ternopil, Kherson, Chernivtsi	-	Donetsk, Chernihiv	-	-

Note: (N) means clustering of regions by the indicator “number of enterprises”; (S) means clustering of regions by the indicator “sales volume”

Source: developed by the author

Special attention should be paid to the results of clustering Ukrainian regions based on water transport indicators due to its significant role in domestic and especially international freight transportation supporting export-import

operations (Table 14). Based on the cluster analysis conducted, the following regional strategies for the development of TLI are proposed to be implemented during the war period and during the post-war revival of the Ukrainian economy.

Table 14. Matrix of integration of cluster analysis results based on the indicators “number of enterprises” and “sales volumes” of transport and logistics infrastructure enterprises (freight maritime and river transport)

Clusters	CL1 (S) (Zero or Minimal Sales Volume)	CL2 (S) (Medium Sales Volume)	CL3 (S) (High Sales Volume)
CL1 (N) (Zero or Minimal Number of Enterprises)	Ivano-Frankivsk, Zaporizhzhia, Rivne, Kharkiv, Cherkasy, Vinnytsia, Zakarpattia, Kirovohrad, Mykolaiv, Khmelnytskyi, Lviv, Poltava, Kyiv, Volyn, Dnipropetrovsk, Zhytomyr, Luhansk, Sumy, Ternopil, Kherson, Chernivtsi, Donetsk, Chernihiv	-	-
CL2 (N) (Medium Number of Enterprises)	-	Kyiv	-
CL3 (N) (Large Number of Enterprises)	-	-	Odesa

Note: (N) means clustering of regions by the indicator “number of enterprises”; (S) means clustering of regions by the indicator “sales volume”

Source: developed by the author

Strategy C1(N)-C2(S), CL2(N)-CL2 (S) (Tables 13-14) for City of Kyiv (highly developed TLI centre of Ukraine). During wartime, priority tasks include ensuring the resilience of logistics flows (backup routes, multimodality), development of military and humanitarian logistics, decentralisation of warehouses by relocating part of storage capacities outside the city, and development of smart logistics. In the post-war period, it is economically feasible to establish a national logistics hub in the capital with highly developed innovative logistics services based on smart technologies and integration into the Trans-European Transport Network (TEN-T) and European transport corridors.

Strategy C2(N)-C1(S), C2(N)-C5(S), CL3(N)-CL3(S) (Tables 13-14) for Volyn, Odesa, Lviv regions, which have a high level of ITL development, but uneven logistics flows due to the influence of the war. For these regions, it is considered appropriate, first of all, to implement measures to: strengthen their role as western and southern logistics “gates”, develop and modernise border infrastructure, redirect export flows to these regions and more actively use warehouse capacities. In the post-war period, it is economically feasible to form international logistics clusters (cross-border) with the participation of these regions. As V.S. Antonyuk *et al.* (2018) noted, in the conditions of globalisation, clusters lose their territorial identity and become a form of supply chain management that can cover different countries and regions. This is an ideal theoretical basis for creating cross-border clusters. Ukraine is integrated into international transport corridors (4 out of 10 Pan-European transport corridors (3, 5, 7, 9); 4 transcontinental corridors (Europe-Asia, TRACECA, Baltic-Black Sea, Black Sea Ring). This applies to Volyn and Lviv regions – corridors to Poland, Slovakia, Hungary; Odessa region – sea and multimodal corridors to the EU, the Caucasus, Turkey. The objective basis for the creation of international clusters is that international cargo flows intersect in these regions, there are multimodal hubs, and there is potential for infrastructure integration. In particular, Volyn – Yagodyn, the border with Poland; Lviv region – Rava-Ruska, Krakovets, international road and rail corridors; Odessa region – sea ports, the Danube cluster, international sea routes. In the process of forming international clusters, the ports of Odessa, the development and modernisation of intermodal terminals, attraction of foreign investments.

Strategy C3(N)-C1(S), C3(N)-C3(S), C3(N)-C5(S) (Table 13) for regions with average development of TLI: Ivano-Frankivsk, Zaporizhzhia, Rivne, Kharkiv, Cherkasy, Vinnytsia, Zakarpattia, Kirovohrad, Mykolaiv, Khmelnytskyi, Poltava. In wartime, the strategic orientation is to use these regions as transit zones with local optimisation of transportation, redirection of logistics flows to safe regions, and support for the further functioning of basic logistics. In the post-war period, it is considered advisable to create regional logistics hubs based on the modernisation of transport and warehouse infrastructure and the introduction of smart logistics.

Strategy C4(N)-C4(S), C4(N)-C5(S) (Table 13) for regions with above-average development of TLI (Dnipropetrovsk, Kyiv). In wartime, it is considered advisable to use these regions as industrial and logistics centres for the needs of military logistics with the provision of protection of critical infrastructure from attacks by the Russian Federation. In the post-war period, these regions should be used for the construction and development of existing industrial and logistics parks, which will ensure the integration of production and logistics, support for national exports, and expansion of the use of rail transport.

Strategy C5(N)-C1(S), C5(N)-C3(S) (Table 13) for regions with a low level of development of TLI: Zhytomyr, Luhansk, Sumy, Ternopil, Kherson, Chernivtsi, Donetsk, Chernihiv. The most important measures in the strategic aspect are the development of evacuation logistics and the formation of humanitarian corridors, support for local logistics to meet the needs of the population, and minimising losses of logistics infrastructure. For the post-war period, state support for the development and reconstruction of TLI in these regions is especially important; implementation of state investment programs aimed at stimulating business and forming logistics networks.

Thus, the main strategic directions of the development of Ukraine’s transport and logistics infrastructure in wartime are an orientation towards the western regions, decentralisation of logistics, and ensuring flexibility of routes in accordance with the main criteria: safety, speed, and efficiency. In the post-war period of the revival of the country’s transport and logistics infrastructure, the main priorities are defined as integration with the EU, the development of logistics hubs, and the intellectualisation of logistics in accordance with the criteria: integration, innovation, and efficiency to be the main priorities.

● DISCUSSION

The results of the cluster analysis confirm that the development of Ukraine's transport and logistics infrastructure in wartime has a pronounced asymmetric and uneven nature, which is manifested in the significant differentiation of regions in terms of logistics potential and economic activity. The identification of clusters with different characteristics (from a highly developed centre – Kyiv to regions with a low level of development) allowed not only to identify spatial imbalances, but also to substantiate the need to form differentiated regional development strategies.

The results obtained are consistent with the conclusions of T. Charkina *et al.* (2024), who identify key areas for restoring Ukraine's transport infrastructure through the development of multimodal transportation, modernisation of transport corridors and digitalisation. T. Charkina *et al.* (2024) determine strategic directions for the development of domestic transport and logistics infrastructure, which correspond to global trends and are represented by the expansion of multimodal transportation, transport hubs and corridors; attracting public and private investments; optimal tariff policy, modernisation of border crossing points; introduction of information systems and digital technologies. The common understanding is that the transport and logistics system is being transformed towards integration with European markets and strengthening the role of border and port regions. At the same time, unlike the aforementioned authors, who focus on macro-level economic models and stabilisation mechanisms, this study proposes a micro-regional approach based on clustering of regions and allows for detailed strategic decisions depending on the level of infrastructure development.

The results of the study on the development of cargo maritime transport are consistent with the conclusions of M. Hryhorak *et al.* (2022) and O.M. Melnyk (2023). Similarly, the results of the study correlate with the approach of K. Kriachko *et al.* (2024), who consider strategic planning of transport infrastructure as a key tool for ensuring its stability in war conditions. In particular, their emphasis on the need for strategy adaptability, risk-taking, and the use of digital tools is consistent with the regional strategies proposed in this paper. K. Kriachko *et al.* (2024) proposed the introduction of a mechanism for strategic planning of Ukraine's transport and logistics infrastructure in wartime, which includes procedures and rules for developing strategic plans, measures to ensure strategic planning, targeted development strategies, and covers the formation of a strategic vision, defining infrastructure development goals, analysing external and internal factors, adjusting plans taking into account military risks, and monitoring the implementation of strategies. The proposed mechanism is aimed specifically at ensuring the sustainability, efficiency, and innovation of the transport system even in crisis conditions. The authors also pay special attention to the introduction of modern technologies and digital tools. However, unlike their conceptual model, the presented study focuses on empirically substantiating strategies through cluster analysis, which allows increasing the practical relevance of the results.

The results obtained are significantly consistent with the conclusions of M. Stehnei *et al.* (2026), who emphasise the formation of infrastructure asymmetries in the transport and logistics system of Ukraine. M. Stehnei *et al.* (2026)

in their research focus on the emergence of significant asymmetry in the functioning of the transport and logistics system of Ukraine as a result of military operations: asymmetry in the throughput capacity of logistics capacities, structural asymmetry in the use of different types of transport, interregional asymmetries in the development of new centres of logistics activity, asymmetry in the provision and support of transport infrastructure, digital asymmetry in the development of state and private companies, institutional asymmetry in the processes of regulating transport and logistics activities in accordance with EU norms and standards. The clusters identified in this study actually empirically confirm the existence of such asymmetries, in particular between leading regions (Kyiv, Odesa, Lviv regions) and regions with a low level of development. At the same time, if the mentioned authors focus on the characteristics of the types of asymmetries (structural, institutional, digital), then this work expands their approach, offering a tool for their quantitative measurement and grouping of regions.

The results of the study are also consistent with the provisions of S.V. Smerichevska & L.M. Ivanenko (2025) regarding the need to introduce smart technologies, digitalisation and integration of transport systems. S.V. Smerichevska & L.M. Ivanenko (2025) proposed a five-component paradigm for implementing a model for restoring Ukraine's transport and logistics infrastructure based on smart technologies, which is based on: digitalisation and automation (implementation of software complexes, smart monitoring, AI); adaptability (the ability of infrastructure to operate in crisis conditions, including military ones); environmental friendliness (development of "green" logistics solutions, emission reduction, energy efficiency); integration (combination of different types of transport, digital platforms, international standards); safety and cybersecurity. The regional development strategies proposed in the work (in particular for leading clusters and regions with an average level of development) provide for the implementation of SMART logistics, which confirms the commonality of approaches. At the same time, unlike the conceptual model of these authors, this study specifies which regions need the priority implementation of such technologies.

In the context of the study by N.I. Mykhailuk (2023), which identifies the main challenges for the development of transport logistics in wartime (destruction of infrastructure, increased costs, disruption of supply chains), the results obtained fully confirm the above trends. In particular, the identification of clusters with a low level of development directly reflects the consequences of these challenges. At the same time, in contrast to the predominantly descriptive nature of the study by N.I. Mykhailuk (2023), this work provides a quantitative assessment of the consequences of war at the regional level. It is also important to compare it with the study by V.S. Antonyuk *et al.* (2018), which substantiates the cluster model of the development of transport and logistics infrastructure. The idea of forming logistics clusters as a tool for increasing the efficiency of supply chains has found further development in this work. However, if in the mentioned study the cluster approach is considered as an organisational and economic model, then in this work it is used as an analytical tool for diagnosing regional disparities and forming strategies.

Thus, the conducted research complements existing scientific approaches, combining their conceptual provisions with quantitative analysis. Unlike most works that focus on national or industry aspects of the development of transport and logistics infrastructure, this study proposes a methodological approach to the formation of differentiated regional strategies based on cluster analysis. The results obtained confirm that the key characteristics of the current state of the transport and logistics system of Ukraine are: territorial uneven development; concentration of logistics activity in a limited number of regions; increasing role of road transport and border regions; the need to adapt logistics systems to conditions of increased risks. In summary, it should be noted that, unlike existing studies, the proposed approach allows not only to describe the transformations of transport and logistics infrastructure, but also to form practically oriented solutions for its development in the conditions of the war and post-war periods, which determines its scientific novelty and applied value.

● CONCLUSIONS

The war caused an uneven, asymmetric and multidimensional impact on the transport and logistics infrastructure of Ukraine, which differs significantly between regions. The proposed methodological approach to justifying and developing differentiated strategies for the development of the transport and logistics infrastructure of individual regions of Ukraine consisted in grouping regions by the level of development of the transport and logistics infrastructure, taking into account the infrastructure potential and the level of logistics activity in war conditions. Cluster analysis of the logistics infrastructure of Ukraine in a regional context by indicators of “number of enterprises” and “sales volume” of transport and logistics infrastructure enterprises (freight road transportation, freight rail transportation, warehousing, freight water transportation) became the basis for the formation of differentiated strategies for the development of individual groups of regions.

The following regions were identified. Regions that are leaders, characterised by highly developed transport

and logistics infrastructure and its active functioning in wartime (Kyiv city). Regions that are characterised by high development of transport and logistics infrastructure, but have certain imbalances in the distribution of logistics flows due to the impact of the war (Volyn, Odesa, Lviv regions). Regions that are characterised by an above-average level of development of transport and logistics infrastructure and high or specialised logistics activity during the war (Dnipropetrovsk, Kyiv regions). Regions that are characterised by a medium-developed transport and logistics infrastructure and a medium or low level of logistics activity (Ivano-Frankivsk, Zaporizhzhia, Rivne, Kharkiv, Cherkasy, Vinnytsia, Zakarpattia, Kirovohrad, Mykolaiv, Khmelnytskyi, Poltava regions). Regions characterised by a low level of development of transport and logistics infrastructure and low logistics activity (Zhytomyr, Luhansk, Sumy, Ternopil, Kherson, Chernivtsi, Donetsk, Chernihiv). The groups of regions identified as a result of the cluster analysis have different levels of infrastructure destruction, uneven accessibility of ports, corridors and multimodal nodes, differences in throughput and institutional conditions, specific needs of individual industry regions, different intensity of risks and logistics constraints. The proposed differentiated strategies cover regions with similar logistics problems and potential, aimed at optimising investments and state support, as well as increasing the resilience of logistics chains in war and post-war periods. Further scientific research should be focused on the formation of regional logistics policy, clarification of priorities for investment in transport infrastructure, development of strategies for equalizing regional development, and improvement of SMART logistics systems.

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● CONFLICT OF INTEREST

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Використання кластерного аналізу транспортно-логістичної інфраструктури України для формування стратегій розвитку регіонів

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Анотація. Війна спричинила нерівномірні та асиметричні зміни в транспортно-логістичній інфраструктурі України, що зумовило необхідність дослідження рівня її розвитку в окремих регіонах, з подальшим їх групування та розробленням диференційованих стратегій стабілізації й подальшого розвитку логістики в період воєнного стану та післявоєнного відновлення економіки. Метою статті був розвиток методичних підходів щодо обґрунтування та розробки стратегій стабілізації та розвитку транспортно-логістичної системи України в воєнний та післявоєнний період з урахуванням асиметричного та нерівномірного впливу війни на регіони. Для досягнення мети було обрано метод кластерного аналізу для групування областей України за потенціалом/функціонуванням їх транспортно-логістичної інфраструктури, рівень розвитку якої оцінювався як дуже високий, високий, підвищений, середній та низький. В результаті проведеної кластеризації та групування областей України за показниками «кількість підприємств» (характеризує логістичний потенціал), «обсяги реалізації підприємств транспортно-логістичної інфраструктури» (функціонування логістики) запропоновано п'ять диференційованих стратегій на період воєнного стану та у післявоєнний період, які охоплюють наступні аспекти стратегічного розвитку логістики регіонів України: інфраструктурний, логістично-операційний, безпековий, інноваційно-технологічний, інтеграційний (міжнародний), економічний, просторово-регіональний та соціально-гуманітарний. До ключових стратегічних напрямів розвитку транспортно-логістичної інфраструктури України в умовах війни віднесено переорієнтацію логістичних потоків на західні регіони, децентралізацію логістичних процесів та забезпечення гнучкості маршрутів відповідно до критеріїв безпеки, оперативності й ефективності. У післявоєнний період пріоритетами відновлення та розвитку транспортно-логістичної системи визначено інтеграцію до європейського транспортного простору, розвиток сучасних логістичних хабів і впровадження інтелектуальних логістичних рішень. Практична цінність дослідження базується на тому, що комплексна реалізація запропонованих стратегій дозволить забезпечити стійкість логістичних систем у воєнний період та створити передумови для ефективного післявоєнного відновлення і інтеграції України у глобальні транспортно-логістичні мережі

Ключові слова: регіональна логістична інфраструктура; логістика; смарт-логістика; кластеризація; стратегічний підхід