

INTERMODAL AND MULTIMODAL EXPORT LOGISTICS OF UKRAINIAN AGRICULTURAL PRODUCTS DURING MARTIAL LAW

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Abstract. Description of the problem. In the conditions of full-scale Russian aggression in Ukraine, the export logistics of agricultural products abroad has broken down. As a result of blockade of the ports of the Black and Azov seas, the occupation of a part of the regions of Ukraine, it became necessary to use alternative types of logistics and transportation of agricultural products throughout the country and abroad. The majority of the logistics of Ukrainian agricultural products abroad was carried out by sea transport. Taking into account the conditions of wartime and ensuring food security in the world, it became necessary to activate road and rail transport and their combination – the use of intermodal and multimodal transport using the geographical capabilities of the neighbouring countries of the EU. Research methods: comparative analysis of types of transportation, economic and statistical analysis of volumes of transportation of Ukrainian agricultural products, forecasting of export logistics routes of Ukrainian agricultural products to the countries of the EU. The main research results. An analysis of the use of different types of transport in transportation and export of Ukrainian agricultural products was carried out. Alternative directions of export logistics of Ukrainian agricultural products using intermodal and multimodal transport to the countries of the EU have been identified. Ways of developing intermodal and multimodal logistics of Ukrainian agricultural products with the aim of increasing the volume of transportation and export are proposed. Using the possibilities of intermodal and multimodal transport, the need to create transport hubs in the border territories of Ukraine and the countries of the EU is substantiated. The need to improve the transport infrastructure of Ukraine and the countries of the EU based on intermodal and multimodal export logistics is substantiated.

Keywords: road transport, rail transport, combined transport, logistics, agricultural products.

Introduction

The logistics of Ukrainian agricultural exports have faced unprecedented challenges since the onset of the martial law. As a key global supplier of agricultural products, Ukraine plays a crucial role in international food security. However, the ongoing military aggression has disrupted traditional transportation routes, necessitating a shift towards intermodal and multimodal logistics solutions to maintain the flow of goods to international markets. In this context, intermodal and multimodal logistics have emerged as critical strategies to maintain the flow of agricultural products to international markets.

Intermodal logistics, which involves the seamless transfer of goods using multiple modes of transportation such as rail, road, sea, has become essential in navigating the constraints imposed by martial law. Similarly, multimodal logistics, where a single transport contract encompasses various transportation methods, offers greater flexibility in overcoming infrastructural and geopolitical challenges. The blockade of key Black Sea ports, damaged rail networks, and shifting border controls have all required innovative logistical strategies to ensure the continued export of agricultural products.

We have reviewed scientific literature sources that study and solve the problems of export logistics of Ukrainian agricultural products, the use of intermodal and multimodal transport during the martial law. The study by Muravska L. and Ruda T. examines changes in agricultural exports due to the breakdown of existing supply chains in the context of seaport blockades and identifies prospects for export development with the use of combined transport [1]. Chaika-Petegrych L. explores the theoretical and applied foundations of integration different modes of transport aimed at achieving the optimality of intermodality and modality criteria [2]. Kramskiy S., Tarakanov M. and Antonyuk P. focus on achieving optimal integration into global value chains in agricultural markets, in particular, they point out that this can be achieved through the development of transport infrastructure (seaports) and improvement of logistics export flows [3]. The authors such as Zeller V. and Kramskiy S. consider intermodal transport in terms of time and security, which is especially relevant given the transit logistics during the martial law in Ukraine [4]. In the paper, Lomotko D. and Prymachenko H. reflect the results of research on the development of multimodal rail transport in Ukraine based on containerisation of

cargo movement [5].

The research of scholars who have studied the use of intermodal and multimodal transport using the capabilities of the EU countries deserves considerable attention. The results of the authors' research show that due to the growing need for multimodal transport in Ukraine and the EU for the transport of agricultural products, especially by rail, an important factor is cost optimisation and environmental protection, as well as the use of network systems [6; 7]. The research by Rokicki T., Ochnio L., Bórawski P., Bełdycka-Bórawska A. and Żak A. is based on the assessment of the use of different modes of transport in the system of intermodal transport development in selected EU countries [8]. The authors Yanovska V., Król M., Pittman R. consider current trends in the logistics of Ukrainian agricultural products during martial law and propose alternative logistics routes for export of agricultural products to certain EU countries [9].

Despite the existence of studies on the above issues, further research is needed to develop alternative export logistics for Ukrainian agricultural products using intermodal and multimodal transport, create transport hubs on the border areas of Ukraine and the EU countries, and improve the transport infrastructure.

Materials and methods

Intermodal transportation refers to the movement of goods using multiple modes of transport (e.g. rail, road, sea, and air) under a single contract or bill of lading, without handling the freight itself when changing modes. The goods are typically packed in standardized containers or intermodal loading units (ILUs), which can be easily transferred between different transport modes (e.g. from ship to rail or from rail to truck) using specialized equipment (Fig. 1).

Multimodal transportation refers to the movement of goods using multiple modes of transport (e.g. rail, road, sea, and air) under the responsibility of a single logistics provider or operator, who manages the entire journey from origin to destination (Fig. 2). Unlike intermodal transportation, which focuses on the seamless transfer of standardized containers between modes, multimodal transportation emphasizes the integration of services under one contract, regardless of whether the goods are transferred between modes in the same container or not.



Fig. 1. Schematic diagram of intermodal transportation



Fig. 2. Schematic diagram of multimodal transportation

Between 2021 and 2024, the transportation of Ukrainian agricultural products underwent significant changes due to geopolitical events, notably the Russian aggression in 2022, which disrupted traditional export routes and necessitated the development of alternative logistics – use of intermodal and multimodal transportation. In Table 1 data of the transportation of Ukrainian agricultural products by various types of transport for 2021-2024 are summarized. The data for 2024 include projections based on current trends and potential scenarios, as precise statistics for 2024 are not yet available. The table shows that in 2021 maritime transport dominated, with 90% of exports of Ukrainian agricultural products shipped via the Black Sea ports (Odesa, Chornomorsk, Pivdennyi). Rail, road, and river

transport were secondary, primarily used for domestic distribution and exports of Ukrainian agricultural products to neighboring countries.

Table 1

Exports of Ukrainian agricultural products by various types of transport, 2021-2024

Transport type	2021 (pre-war)	2022 (post-invasion)	2023 (up to September)	2024 (projections)
Maritime	~50-55 million tons	~16 million tons (Black Sea Grain Initiative)	~10-12 million tons (Humanitarian corridor)	~10-25 million tons (Depending on the Black Sea security)
Rail	~10-12 million tons	~15 million tons	~12-14 million tons	~15-18 million tons
Road	~3-4 million tons	~3-4 million tons	~4-5 million tons	~5-6 million tons
River (Danube)	~5-6 million tons	~8-10 million tons	~10-12 million tons	~12-15 million tons
Total Exports	~65-70 million tons	~50-55 million tons	~35-40 million tons	~40-60 million tons

Source: authors' research based on [10; 11]

In 2022 the Russian blockade of the Black Sea ports severely disrupted maritime exports of Ukrainian agricultural products. The Black Sea Grain Initiative (July 2022) allowed limited maritime exports (to 16 million tons in 2022). Rail and river transport became critical, with significant increases in volumes. Overland exports of Ukrainian agricultural products to the EU (via rail and road) and Danube River exports grew substantially. In 2023 (up to September) the suspension of the Black Sea Grain Initiative in July 2023 reduced maritime exports of Ukrainian agricultural products. Ukraine established a humanitarian corridor in August 2023, enabling limited maritime exports (10-12 million tons up to September). Rail and river transport remained vital, with further increases in volumes. Total exports of Ukrainian agricultural products for 2023 are lower than in 2022 and 2021 due to the Black Sea blockade. In 2024, maritime transport will remain at the level of 2023 dependent on the security situation in the Black Sea. Rail and road transport remain stable and increase. Danube River exports remain critical, potentially reaching 12-15 million tons.

Results and discussion

Since the Russian aggression in 2022, Ukraine has developed alternative export of agricultural product routes to the EU using intermodal and multimodal transport systems. These involve a combination of road, rail, river, and sea transport to bypass the blocked Black Sea ports and ensure agricultural product exports (Table 2). According to the information in the table, Ukraine used to transport agricultural products through the ports of Izmail, Reni and Ust-Dunaisk on the Danube. Romania's Constanța port became a critical hub, handling up to 3 million tonnes of agricultural products per month. Barges transport agricultural products from Ukraine's river ports to Romania for shipment to global markets. Ukraine uses Polish railroads to move agricultural products to Gdańsk and Gdynia ports. The Baltic States (Lithuania, Latvia) allow transshipment via Klaipėda, Riga, and Ventspils. Adriatic Route runs through Slovenia's Koper port and Italy's Trieste and Venice ports provide another maritime link. Rail transport connects Ukraine via Slovakia and Hungary. EU Land Transport runs through direct rail and road exports of Ukrainian agricultural products to Poland, Slovakia, Hungary, and Romania regional markets.

Intermodal transport via EU ports is carried out through the following processes: agricultural products are transported by rail or truck from Ukraine to the EU border crossings → transferred to rail or river transport for delivery to EU ports → from EU ports, agricultural products are shipped to global markets.

Multimodal Transport via Rail and Road is carried out through the following processes: agricultural products are transported by rail to the EU countries (Poland, Romania, Hungary) and then by road or

rail to Germany for further distribution, by road or sea to Italy, by road or rail to Austria.

Table 2

**Alternative export of Ukrainian agricultural product routes
using intermodal and multimodal transport to EU**

Route	Transport modes	Key destinations	Challenges
Danube River Route	Rail/Road → River → Seaports	Romania (Constanța), Bulgaria (Varna)	Limited port capacity, congestion
Polish Corridor	Rail/Road → EU Rail → Baltic Ports	Poland (Gdańsk, Gdynia), Germany	Infrastructure bottlenecks, border delays
Baltic Sea Route	Rail → Lithuanian/Latvian Ports	Lithuania (Klaipėda), Latvia (Riga, Ventspils)	Distance, high costs
Adriatic Route	Rail → Slovenian/Italian Ports	Italy (Trieste, Venice), Slovenia (Koper)	Rail infrastructure, costs
Land Routes via Road and Rail	Road/Rail → EU Markets	Poland, Slovakia, Hungary, Romania	Capacity limits, protests by local farmers

The positive aspects of the Danube River Route include the following: cost-effective for bulk cargo (barges are cheaper than rail/road); avoids Black Sea blockade, providing a safer alternative; growing capacity with EU investments in Romanian/Bulgarian ports. The negative aspects of this transport route are: congestion at key ports (Constanța, Izmail, Reni); seasonal limitations (low water levels in summer/winter); slower transit times compared to rail. In our opinion, the positive aspects of the Polish Corridor are: fastest land route to major EU markets (Germany, Netherlands); high port capacity in Gdańsk/Gdynia (Poland); well-developed EU rail links for onward distribution. Border bottlenecks (long queues at Poland-Ukraine crossings); farmer protests disrupting transit (Polish farmers oppose Ukrainian grain) and higher rail costs compared to river transport are the negative aspects of this route. The positive aspects of the Baltic Sea Route include the following: stable and secure (no farmer protests like in Poland); good port access (Klaipėda, Riga, Ventspils); EU-supported infrastructure (Rail Baltica project improving connectivity). The negative aspects of this transport route are: longer distances increase costs; limited rolling stock (not enough rail wagons for high demand); higher logistics costs than the Danube route. We are convinced that positive aspects of the Adriatic Route are: access to southern EU markets (Italy, Balkans); less congestion compared to Polish/Baltic routes; potential for growth with better rail integration. Underdeveloped rail links (slow transit, gauge changes); high costs (more expensive than the Danube or Polish routes); limited port capacity in Koper/Trieste for large volumes are the negative aspects of this route. The positive aspects of the Land Routes via Road & Rail include the following: most flexible (direct delivery to buyers in Poland, Hungary, Romania); no port dependency (avoids seaport congestion); faster for small shipments (trucks can bypass rail delays). The negative aspects of this transport route are: high costs (road transport is expensive for bulk cargo); border delays (customs checks, paperwork); farmer blockades (especially in Poland, Slovakia, Hungary).

A numerical analysis showing the positive and negative features of each transport route using key logistics performance indicators is presented in Table 3. Metrics are scored from 1 (poor) to 5 (excellent) for easy comparison.

The results of the numerical evaluation show that the Danube River Route gains significantly in terms of transport costs, but loses out due to slower speeds due to river transit and port congestion. The Polish Corridor has high port capacity (Gdańsk/Gdynia), fastest land route and good rail links, but high transport costs and farmer protests reduce the attractiveness of this route.

The Baltic Route looks the best among the transport routes evaluated due to the port capacity (Klaipėda, Riga), reliability (no major protests or blockades) and infrastructure (Rail Baltica). The Adriatic Route has advantages in terms of reliability and capacity of seaports (Koper, Trieste), but has significant disadvantages in terms of high transport costs, slow due to poor rail links and poor rail infrastructure. Land Routes (Road/Rail) proved to be the least efficient due to high transportation costs (trucks are very expensive for bulk cargo), capacity (limited by truck/railcar availability) and reliability (border delays and farmer blockades).

Table 3

Numerical evaluation of Ukrainian agricultural export routes to EU

Route	Cost (1-5)	Speed (1-5)	Capacity (1-5)	Reliability (1-5)	Infrastructure (1-5)	Total (25 max)
Danube River Route	4	2	3	3	3	15
Polish Corridor	2	4	4	2	4	16
Baltic Sea Route	3	3	4	5	4	19
Adriatic Route	2	2	3	4	2	13
Land Routes via Road and Rail	1	4	2	2	3	12

Source: authors' evaluation

Taking into account the martial law in Ukraine, the state of the transport infrastructure, the level of support from the EU countries and the dynamics of the global agricultural market, we forecast transport routes for export of Ukrainian agricultural products to the EU using intermodal and multimodal transport (Table 4).

Table 4

Forecasted transport routes for export of Ukrainian agricultural products to EU using intermodal and multimodal transportation

Route	Main transport modes	Key EU destinations	Forecast and developments
Danube River & Black Sea	Rail/Road → River → Seaports	Romania (Constanța), Bulgaria (Varna, Burgas)	Expected to remain critical with planned port expansions in Romania and increased barge capacity.
Poland & Baltic Corridor	Rail/Road → EU Rail → Baltic Ports	Poland (Gdańsk, Gdynia), Lithuania (Klaipėda), Germany	Investment in rail gauge compatibility to speed up transshipment. Increased cooperation with Poland and the Baltic states.
Adriatic Route	Rail → Slovenian/Italian Ports	Italy (Trieste, Venice), Slovenia (Koper)	Growth expected due to shorter transit times and reduced congestion at the Black Sea ports.
Direct EU Land Transport	Rail/Road → EU Markets	Poland, Slovakia, Hungary, Romania	Will remain essential for regional agricultural product supplies, but faces border protests and regulatory restrictions.
New Alternative Routes	Rail → Croatian Ports, Greek Ports	Croatia (Rijeka, Ploče), Greece (Thessaloniki)	Emerging routes, still limited but growing due to EU infrastructure funding.

Source: authors' proposal

In our opinion, the key promising areas for the development of logistics routes for the export of Ukrainian agricultural products to the EU using intermodal and multimodal transport will be increased depending on the Danube and the Black Sea, with the Romania' Constanța port remaining the largest alternative hub for exports. To increase the capacity of the Danube River, investments in infrastructure are needed to boost barge capacity and port efficiency. We see the expansion of rail and the Baltic Sea exports as a promising area – Poland and the Baltic states will increase their rail capacity for Ukrainian agricultural products, and Lithuania's Klaipėda port and Poland's Gdańsk port are being expanded to accommodate more Ukrainian shipments. The Adriatic and Southern EU corridors will grow – Italian and Slovenian ports (Trieste, Venice, Koper) will receive more Ukrainian agricultural exports due to better rail connectivity. Croatian and Greek ports (Rijeka, Thessaloniki) could be a new alternative destination. For EU land transport, we see challenges in terms of border congestion and protests by EU farmers, which could limit road transport expansion.

In order to improve the transport infrastructure of Ukraine and the EU, increase the volume of

transportation and export of Ukrainian agricultural products, we have proposed ways to development intermodal and multimodal logistics.

1. Infrastructure development – upgrading Ukraine’s rail infrastructure; changing railway gauges at border crossings to reduce delays when transferring goods between Ukrainian (broad gauge) and EU (standard gauge) rail systems; expanding rail terminals, storage facilities, and loading/unloading infrastructure at key hubs; modernizing the road infrastructure at key border crossings (e.g. Poland, Romania, Hungary) to reduce bottlenecks; building logistics hubs near border crossings to facilitate the transfer of goods between trucks and trains; expanding river ports; increasing the number of barges and improve their efficiency to transport more agricultural products to EU ports; enhance the EU port capacity.
2. Digitalization and automation – digital customs procedures (Single-Window System); using IoT and blockchain technology to track shipments in real time, improving transparency and efficiency; developing automated terminals at border crossings and ports to speed up the transfer of goods between transport modes; using AI-driven logistics platforms to optimize route planning and reduce transportation costs.
3. Policy and regulatory support – aligning customs and transportation regulations between Ukraine and the EU to streamline cross-border trade; reducing bureaucratic hurdles for exporters by simplifying documentation and inspection processes; providing financial support to Ukrainian exporters and logistics companies to offset higher costs of intermodal and multimodal transport.
4. Strengthening logistics networks – building intermodal hubs near major border crossings (e.g. Poland-Ukraine, Romania-Ukraine) to facilitate the transfer of goods between rail, road, and river transport; offering integrated logistics services (e.g. storage, packaging, customs clearance) at these hubs to improve efficiency; expanding the Danube-Black Sea and the Baltic-Adriatic multimodal corridors.
5. Monitoring and evaluation – tracking KPIs such as transportation time, cost, and volume to measure the success of intermodal and multimodal logistics initiatives; using data analytics to identify bottlenecks and optimize logistics operations; establishing feedback loops with exporters and logistics providers to identify areas for improvement; updating strategies based on changing market conditions and technological advancements.

Thus, by expanding the infrastructure, adopting digital solutions, improving regulations, and integrating further with the EU, Ukraine can enhance intermodal and multimodal logistics, boosting agricultural export volumes while ensuring more resilient and cost-effective transportation.

Conclusions

1. Intermodal transportation is a versatile and efficient logistics solution that leverages the strengths of multiple transport modes to optimize supply chains. Multimodal transportation is a comprehensive and customer-centric logistics solution that integrates multiple transport modes under a single operator. For Ukraine, particularly during the martial law, intermodal and multimodal transportation offers a resilient and flexible way to maintain the flow of agricultural products export.
2. During the martial law and blockade, intermodal and rail transport have proven to be critical alternatives to maritime route export of Ukrainian agricultural products, the need to use the potential and transport agricultural products across the Danube River has increased, the smallest volume of agricultural products was transported by road.
3. The main alternative routes are investigated for the use of intermodal and multimodal transport for the export of Ukrainian agricultural products to the EU. These include the Danube River route, Polish Corridor, Baltic Sea route, Adriatic route, land routes via road and rail. The positive and negative aspects of each transport route are identified. A numerical evaluation of transport routes was carried out, which revealed that the Baltic Route is the most optimal by logistics performance indicators.
4. The forecasted transport routes for the export of Ukrainian agricultural products to the EU using intermodal and multimodal transportation are proposed, the seaport in Romania and the increase in its throughput capacity, cooperation with Bulgarian seaports, expanding cooperation between Polish seaports and those in the Baltic States, Italy and Slovenia, creating new routes in Croatia and Greece, and actively using rail and land transport with various combination options.

5. Ways are proposed to development intermodal and multimodal logistics for Ukrainian agricultural products through an integrated approach that combines infrastructure investment, digitalisation, political support, strengthening logistics networks and sustainable development initiatives.

Author contributions

Conceptualization, M.B.; methodology, M.B. and A.S.; validation, M.B. and M.K; formal analysis, M.K and M.S.; investigation, M.B., A.S., M.K. and M.S.; data curation, M.B., M.K. and M.S.; writing – original draft preparation, M.B.; writing – review and editing, A.S. and M.K.; visualization, A.S. and M.S.; project administration, M.B.; funding acquisition, M.B. All authors have read and agreed to the published version of the manuscript.

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