

*The object of the study the digital transformation of transport and logistics processes in the Republic of Kazakhstan, with a focus on the functioning and development of cross-border supply chains. The main problems are related to the fragmentation of information flows, the lack of uniform standards for electronic data exchange and limited compatibility of digital platforms. All this reduces the efficiency and competitiveness of the national logistics system. Based on the analysis of statistical data, international ratings and digitalization cases, the achievements and problems of Kazakhstan's logistics industry have been identified. As a strategic solution, a «data conveyor» methodology is proposed, which provides end-to-end digital support for cargo, transparency of operations, reduction of transaction costs, and increased supply chain resilience. Transportation optimization problems are solved through the introduction of digital solutions such as Single Window, Astana-1 system, e-SMGS, e-CMR projects, the development of smart logistics centers, IoT, blockchain and AI. The results are explained by the introduction of end-to-end digital services and the use of international standards for electronic data exchange, which eliminated fragmentation of information flows and increased integration into global logistics networks.*

*The originality of the results lies in the adaptation of the “data conveyor” methodology to national conditions, which ensures not only technological compatibility, but also the institutional integration of the industry. Thanks to this, a comprehensive systemic solution was proposed.*

*Thus, the study results showed that the digital transformation of Kazakhstan's transport and logistics complex through the implementation of a “data conveyor” and electronic consignment notes reduces costs (up to 4.6 euros per consignment note), while the growth of e-commerce has allowed for an almost twofold increase in revenues in the transport sector in 2022–2024*

**Keywords:** logistics infrastructure, transport infrastructure, digital solutions, transit corridors, digital development

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# IDENTIFYING OPPORTUNITIES TO IMPROVE SUSTAINABLE SUPPLY CHAINS THROUGH DIGITAL TRANSFORMATION OF TRANSPORT AND LOGISTICS INFRASTRUCTURE

**Bibigul Kopbolsyn**

*Corresponding author*

Master of Economic Sciences\*

E-mail: bkopbulsynova@mail.ru

**Assel Jakupova**

Master of Economic Sciences\*

**Bakytgul Bazarova**

Master of Economic Sciences\*

**Aizhan Ibyzhanova**

Candidate of Economic Sciences, Associate Professor\*

**Alberta Abdeshova**

Master of Economic Sciences\*

**Aislu Tyumambayeva**

Senior Lecturer\*

**Assilbek Duskaliyev**

Candidate of Economic Sciences, Associate Professor

Business School

Narxoz University

Zhandosova str., 55, Almaty, Republic of Kazakhstan, 050035

\*Institute of Economics, Information Technology and

Vocational Education

Zhangir Khan University

Zhangir Khan str., 51, Oral, Republic of Kazakhstan, 090009

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## 1. Introduction

In modern conditions of shifting global trade and economic priorities and changing the architecture of foreign trade routes, modernization of logistics processes in cross-border supply chains is becoming particularly relevant. Their resilience and reliability is becoming a key condition for adapting to new challenges, including geopolitical instability and the consequences of global crises. International supply chains are increasingly being formed in the context of two parallel trends: increasing uncertainty in global markets and the rapid development of breakthrough technologies. Therefore, dig-

ital solutions based on artificial intelligence, platform models of interaction, as well as tools that support sustainable development, are becoming a strategic driver of the transformation of global logistics. And research in this area is insufficiently studied at the current stage of digitalization development.

The need to research this industry, ensuring the sustainable and efficient functioning of cross-border chains, provides opportunities to solve problems in the field of transport, logistics and telecommunications infrastructure. The institutional framework for such interaction is formed on the basis of agreements on the integration of digital and logistics initiatives aimed at simplifying international trade,

digitalizing document management and standardizing data exchange. This facilitates the integration of various national supply management systems and increases the compatibility of digital platforms used for tracking, planning and clearance of cargo shipments.

Research in the field of digital transformation of logistics and transport infrastructure is an urgent scientific field, and it opens up many opportunities. For example, the transition to cross-border e-commerce, the improvement of logistics infrastructure, the introduction of end-to-end digital services and the application of international standards for electronic data exchange. All this will make it possible to raise the overall competitiveness of the national logistics industry.

Therefore, research in the field of transport and logistics infrastructure transformation is relevant. The study of the processes of digital transformation of cross-border logistics acquires special scientific and practical significance, reflecting both global trends and regional peculiarities of interaction between countries. Because these countries have different levels of digital development and logistical capabilities.

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## 2. Literature review and problem statement

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The paper [1] shows that the introduction of digital logistics platforms in maritime logistics increases the speed of order processing, improves the quality of service and enhances the integration of supply chain participants. Despite the findings, the paper underexamines the institutional environment and regulatory barriers. This is due to both the limited availability of empirical data and the difficulty of conducting long-term research in this area. Similar conclusions were made in the paper [2], which shows that the integration of Internet of Things (IoT) and artificial intelligence (AI) technologies can significantly increase the adaptability of supply chains to changing market conditions. However, quantitative assessments of environmental and social impacts have so far been fragmented. This is due to limited access to real implementation data and the high sensitivity of this information for businesses.

A study [3] demonstrated that fostering a company culture focused on the use of AI and big data analytics has a positive impact on the efficiency and sustainability of humanitarian supply chains. However, the study did not examine external factors or the quantitative effects of AI application, due to limitations in the methodology and availability of empirical data.

Research [4] demonstrated that Logistics 4.0 technologies, including intelligent cargo tracking and management, contribute to increased transparency and reduced delivery times. Thus, the authors [4] proved that the digital economy increases supply chain resilience through predictive analytics and proactive risk management. However, issues related to the adaptation of these technologies to the conditions of developing countries and the formation of digital corridors at the level of interstate interaction have not been resolved.

The compatibility of such technologies is also attracting attention: for example, research [5] emphasizes that blockchain can strengthen trust between participants in supply chains and ensure data immutability, but simultaneously requires overcoming scalability issues and coordinating standards across borders. Thus, digitalization of logistics is viewed as a strategic direction for improving efficiency, although its implementation entails the need for institutional change and the development of unified data exchange

rules. The literature emphasizes that much depends on the industry's readiness for organizational transformation, as technical solutions must be accompanied by changes in business processes and intercompany interactions. Institutional change and the unification of data exchange rules also remain unexplored, due to the complexity of interstate coordination and the limited empirical data.

A separate block of scientific papers is devoted to the development of cross-border e-commerce. The paper [6] showed that digitalization and online marketplaces stimulate the growth of international shipments of small consignments of goods, which requires logistics adaptation. The study noted that the growth of e-commerce reduces the importance of geographic distance and transforms traditional supply chains. Thus, the development of cross-border e-commerce platforms has led to the emergence of a new trade model. In this model, transactions are conducted online, while physical logistics are restructured to meet the demands of fast international delivery. This area of research lies at the intersection of international business and logistics, demonstrating how digital platforms are changing global supply chains as a whole.

Many studies show that the e-commerce boom has brought to the fore the issues of logistical adaptability and the last mile. For example, study [7] notes that the main challenges lie in the complexity of customs clearance for large numbers of small parcels, insufficient warehouse and courier service capacity, and the need to standardize parcel requirements across different countries. The solution to these problems is seen in the digitalization of the relevant processes: the introduction of 'single window' systems for electronic declaration, the use of automated sorting centers, and the use of big data to forecast loads on courier networks [8]. Thus, e-commerce is becoming an area at the intersection of international business and logistics, demonstrating how digital platforms are changing global supply chains as a whole. At the same time, the literature points to the need for further research in this area, in particular, assessing the long-term consequences of e-commerce growth for traditional carriers, the environmental impact of mass small-batch delivery, and the development of agreed international rules for digital trade.

Study [9] found that digital transparency of operations is directly linked to increased environmental, social, and economic sustainability, as digitalization helps reduce carbon footprints and optimize transport routes. However, questions remain regarding the implementation of these trends in developing countries and the formation of digital corridors, where the level of digital maturity is significantly lower than in countries with developed economies.

The reasons for this may be objective difficulties associated with the lack of unified standards for international document flow, insufficient digital infrastructure, as well as the high cost of integrating national systems with global platforms. All this makes research and practical implementation of solutions difficult.

An option for overcoming the relevant difficulties may be the introduction of pilot digital solutions within key routes, the development of public-private partnerships and phased integration with international digital ecosystems. This is the approach used in the report of the AIFC [10], but in this case the emphasis is on the technical modernization of individual transport corridors (Middle Corridor, North-South) and the digitalization of document flow, which is not yet accompanied by a comprehensive scientific analysis of the effectiveness and long-term effects for the national economy.

In addition, against the backdrop of the above challenges, the development of integrative approaches to data management, such as the ‘data conveyor’ methodology, is becoming particularly important. It provides end-to-end digital support for logistics operations, creating a unified information space for all participants in the supply chain. In the context of the growing need for transparency, efficiency and standardization of information exchange, this concept appears to be a promising direction for further scientific research and practical implementation.

All this allows to assert that it is advisable to conduct a study on the digital transformation of transport and logistics systems and the formation of digital corridors.

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### 3. The aim and objectives of the study

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The aim of the study is to substantiate the strategic importance of digital transformation of transport and logistics infrastructure as sustainable and intelligent supply chains. This will improve logistics efficiency and build trust with international partners.

To achieve this aim, the following objectives were accomplished:

- to assess the infrastructural and digital development of the transport and logistics system of the Republic of Kazakhstan, its contribution to the functioning of key Eurasian transit corridors;
- to assess the effectiveness of the logistics system of the Republic of Kazakhstan based on international ratings and indices (LPI, WEF, OECD, WTO) and identify key factors limiting its development;
- to analyze the dynamics of cargo transportation, warehouse capacity and income of the transport and logistics sector of the Republic of Kazakhstan in 2015–2024 to identify key trends and growth factors;
- to analyze the digital transformation of the transport and logistics complex of the Republic of Kazakhstan and assess the impact of e-commerce on the development of intelligent logistics and international transit corridors.

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### 4. Materials and methods

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The object of the study the digital transformation of transport and logistics processes in the Republic of Kazakhstan, with a focus on the functioning and development of cross-border supply chains.

The main hypothesis of the study is that the implementation of digital solutions and the “data conveyor” methodology in logistics processes in the Republic of Kazakhstan allows for increased efficiency in cross-border supply chains by reducing transaction costs, accelerating data processing, and increasing the transparency and legal validity of transactions. At the same time, assumptions are made about the possibility of adapting international digital practices and the country’s institutional readiness, and simplifications consist of the use of aggregated data, cases, and generalized models without detailing industry and regional differ.

The methods of comparative analysis, analytical visualization, expert assessment, structural-functional modeling, descriptive analytics and bibliometric analysis were used. For example, the empirical basis was statistical data from the National Statistical Bureau, analytical reports of international

organizations, as well as industry materials from the AIFC, Eurasian Development Bank. Data on freight traffic volumes, the structure of logistics services, segment profitability, and digitalization indicators (Single Window portal, ASYCUDA platform, e-SMGS and e-CMR projects) were collected and analyzed.

Comparative analysis, analytical visualization, expert assessment, and structural-functional modeling methods were also used. A digital logistics process diagram was developed, integrating participants in the transport and logistics chain and digital platforms, including national DPM modules and open-source platform solutions.

Descriptive analytics were used to assess the effects of implementing digital solutions: cases of accelerated processing, reduction of transaction costs, increased transparency, and legal significance of operations were considered. The use of bibliometric data and academic publications made it possible to compare international approaches to the digitalization of logistics with the realities in the Republic of Kazakhstan.

Certain simplifications were adopted during the study. Digital logistics processes were modeled in a generalized form without detailed consideration of industry and regional differences. Aggregated statistical data was used, without breakdowns by individual companies or cargo types. The effects of digitalization were assessed primarily through case studies and descriptive analytics, which allowed for the identification of trends but did not involve large-scale econometric modeling. Furthermore, when constructing digital logistics models, key platforms and major participants were considered, while small and niche services were excluded to maintain the integrity of the presented model.

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### 5. Study of global trends and national characteristics of logistics digitalization

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#### 5.1. Assessment of the infrastructural and digital development of the transport and logistics system of the Republic of Kazakhstan

The logistics industry in the Republic of Kazakhstan plays a key role in the country’s economy and in ensuring transit links between Europe and Asia. As the largest country in Central Asia and without direct access to the sea, Republic of Kazakhstan strives to become a transcontinental Eurasian bridge for the flow of goods between East and West. Over the past 5–10 years, the country has been implementing large-scale projects to modernize its transport infrastructure and digitize logistics processes, aimed at unlocking its transit potential.

The Republic of Kazakhstan has a ramified transport network: about 16 thousand km of railways, 95 thousand km of highways, of which 25 thousand km are of international and republican significance. Between the Caspian ports of Aktau and Kuryk, 25 airports, as well as a wide network of conveyors, more than 29 thousand km of oil and gas conveyors. Over the past 15 years, more than \$35 billion has been invested in the development of transport and logistics infrastructure, which has improved the quality of roads and facilities. The share of the transport and logistics sector in GDP increased from 6.2% in 2022 to 9% by 2025.

Republic of Kazakhstan geographical location between China, Russia, Central Asia and the Caucasus determines its role in several key land corridors. The main route of the Belt and Road Initiative (BRI) between China and Europe passes through Republic of Kazakhstan. Today, over 80% of rail freight between China and Europe transits through

Kazakh territory. Two railway crossings on the Chinese border – Dostyk/Alashankou and Altynkol/Khorgos – ensure a steadily growing flow: in 2024, rail freight turnover between Republic of Kazakhstan and China reached a record 32 million tons, with another 11.4 million tons in the first four months of 2025 (13% more than in 2023) [10].

To eliminate bottlenecks, the capacity of these routes is being expanded. Thus, in 2023–2025, a second railway track is being built on the Dostyk-Moiynty section and a bypass route around Almaty. This will significantly increase the carrying capacity and reduce the delivery time of Asia-Europe cargo. Construction has also begun on a new Bakhty-Ayagoz line with the organization of a third railway border crossing with China (Bakhty-Chuguchak). It is predicted that this line will add up to 25 million tons of capacity in the Chinese direction. The Trans-Caspian route (also known as the Middle Corridor, Trans-Caspian International Transport Route, TITR) through Republic of Kazakhstan, the Caspian Sea, the South Caucasus and Turkey is becoming increasingly important. The Republic of Kazakhstan is at the center of this multimodal corridor. This corridor connects land routes from China to the port of Aktau, then by ferry across the Caspian Sea to Azerbaijan and by rail through Georgia and Turkey to Europe. Transport volumes along the Trans-Caspian route are growing significantly against the backdrop of geopolitical changes: in 2022, 1.5 million tons of cargo passed through it, in 2023 – 2.8 million tons, and in 2024 – 4.5 million tons. The Government of Republic of Kazakhstan, together with its partners, has set a target of increasing the capacity of the Middle Corridor to 10–11 million tons per year by 2030. This requires investment and coordinated policies from all countries participating in the corridor (Fig. 1). According to World Bank estimates, with targeted investments and trade procedure reforms, the Middle Corridor's throughput could triple by 2030, and transit times could be cut in half [11–13].

Equally important for the Republic of Kazakhstan is the North-South international transport corridor, connecting Europe with South Asia and other countries. The Republic of Kazakhstan also participates in the eastern branch of this corridor. The Kazakhstan-Turkmenistan-Iran transcontinental railway, commissioned in 2014, is operational, enabling the delivery of cargo to Kazakhstan and the ports of the Persian Gulf. In 2023, plans were discussed for the synchronized development of the eastern route of the North-South corridor. The Republic of Kazakhstan and Turkmenistan, along with several other countries, are participating in this corridor, including by improving infrastructure and removing barriers along the route. To increase the attractiveness of the North-South route, the Republic of Kazakhstan, together with its partners, is also implementing pilot projects to digitalize document flow on the Kazakhstan-Turkmenistan-Iran railway route (introduction of electronic SMGS consignment notes, etc.).

## 5. 2. Evaluation of the efficiency of the logistics system of the Republic of Kazakhstan

The efficiency of Kazakhstan's logistics system is reflected in international indices. In the World Bank's Logistics Performance Index (LPI), the Republic of Kazakhstan ranked 71<sup>st</sup> (with a score of 2.81 out of 5) among 160 countries in 2018, improving its position compared to previous years. By 2023, its position had declined slightly: 79<sup>th</sup> place with a score of 2.7 out of 139 countries (Fig. 2).

Nevertheless, of the Republic of Kazakhstan remains the leader in Central Asia in terms of this indicator. For comparison, its closest neighbors in the region have lower scores: Uzbekistan – 88<sup>th</sup> place (2.6), Kyrgyzstan – 123<sup>rd</sup> (2.3), Armenia – 97<sup>th</sup> (2.5) in 2023, while the world leaders – Singapore, Germany, etc. – score over 4.0 points. Kazakhstan's improvement in the mid-2010s was particularly notable: in the LPI-2016 ranking, the country rose 11 positions to 77<sup>th</sup> place, ahead of Ukraine, Uzbekistan and Kyrgyzstan (146) (Fig. 2).

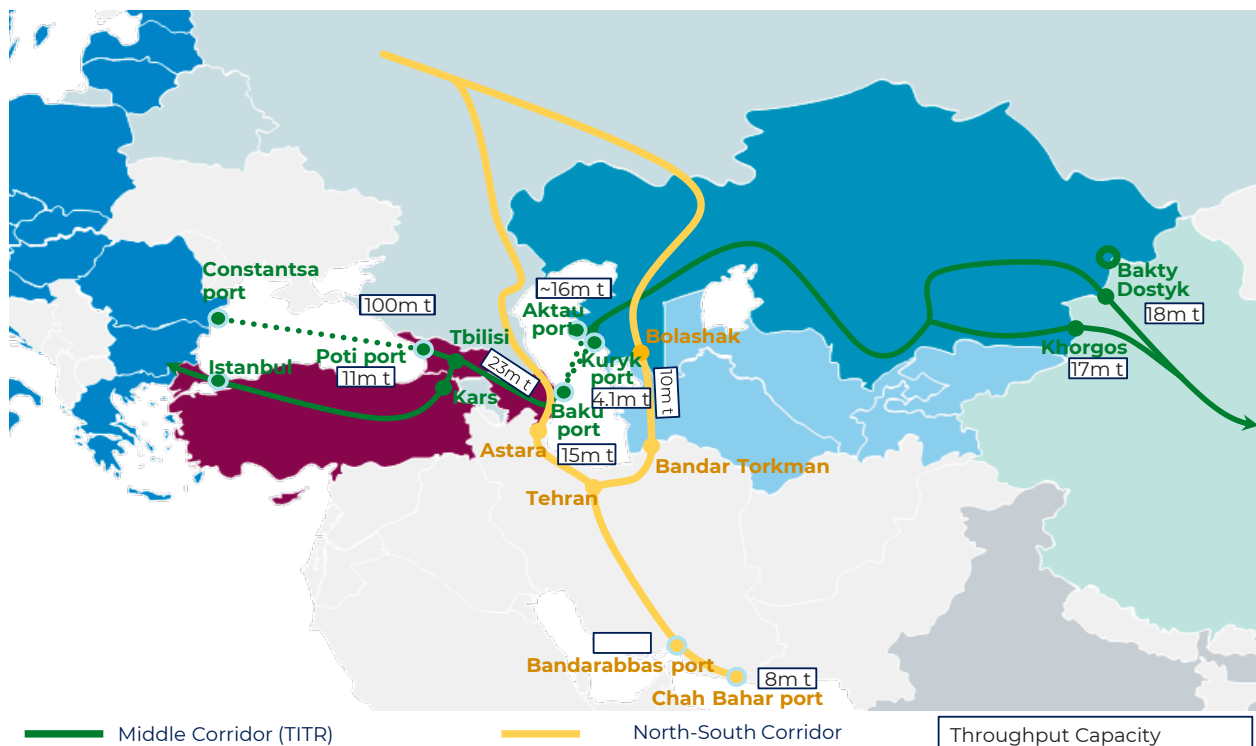


Fig. 1. Capacity of the 'Middle' and 'North-South' transport corridors [10]



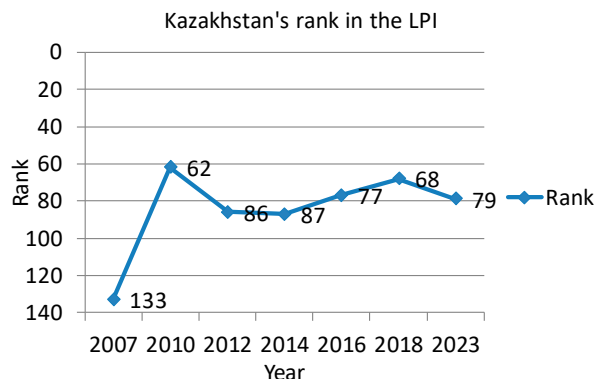


Fig. 2. Kazakhstan's rank in the Logistics Performance Index

Nevertheless, of the Republic of Kazakhstan remains the leader in Central Asia in terms of this indicator. For comparison, its closest neighbors in the region have lower scores: Uzbekistan – 88<sup>th</sup> place (2.6), Kyrgyzstan – 123<sup>rd</sup> (2.3), Armenia – 97<sup>th</sup> (2.5) in 2023, while the world leaders – Singapore, Germany, etc. – score over 4.0 points. Kazakhstan's improvement in the mid-2010s was particularly notable: in the LPI-2016 ranking, the country rose 11 positions to 77<sup>th</sup> place, ahead of Russian Federation, Ukraine, Uzbekistan, Belarus and Kyrgyzstan (146). This progress was due to improvements in infrastructure quality and customs administration. In LPI-2023, the Republic of Kazakhstan received the weakest assessment in the component “delivery time and punctuality” (rank 93). Relatively better indicators are cargo tracking (rank 80) and logistics competence (81) – this indicates the presence of delays at borders and in transit that require attention [10] (Fig. 3).

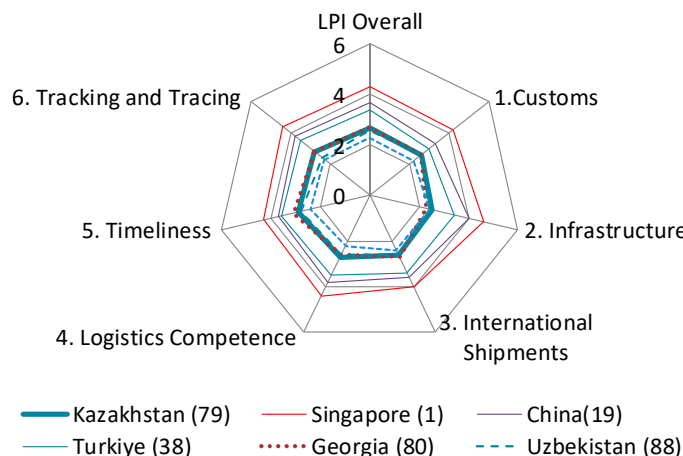


Fig. 3. Comparison of the Republic of Kazakhstan with other countries of the North-South transport corridor in the Logistics Performance Index (LPI)

*Note: the ranking is shown for countries located along the Middle Corridor and Singapore as the leader of the ranking; Azerbaijan is not included in the ranking*

Other international indicators also reflect the situation. In reports by the World Economic Forum (WEF), the Republic of Kazakhstan traditionally receives high marks for railway coverage and infrastructure investment levels, but faces difficulties with the ‘last mile’ and warehouse logistics services. According to OECD reviews, border congestion and administrative barriers increase transport costs in the region. At the same time, the Republic of Kazakhstan has fulfilled all the main obligations under the WTO Trade Facilitation Agreement. As of 2023, the country has implemented almost 100% of measures to simplify trade procedures, including electronic declaration, preliminary information, etc. This confirms the success of reforms in customs and related areas.

### 5. 3. Analysis of the dynamics of cargo transportation, warehouse capacity and income of the transport and logistics sector of the Republic of Kazakhstan

The total volume of freight transport and warehousing in the Republic of Kazakhstan has increased significantly over the decade, with moderate average annual growth rates. Table 1 shows the transport indicators

As can be seen from the Table 1 over the period 2015–2024, the volume of freight transport increased from approximately 662 to 1,090 million tons, and freight turnover increased from 403 to 521 billion ton-kilometers. The average annual growth rate of the industry was 2–3%. The biggest drop occurred in 2020–2021 due to the pandemic (passenger traffic declined, and freight tonnage also decreased slightly). However, the transport industry recovered quickly: freight turnover reached pre-crisis levels as early as 2021, and records were broken in 2023. For example, in January – May 2025, 455.9 million tons of cargo were transported, which is 11.9% more than a year earlier, indicating continued growth.

It is worth noting the changes in the types of transport. Rail transport consistently handles 300–400 million tons per year, with rail freight turnover growing at a faster rate due to transit. Road transport carries the largest volume in terms of tons, although its freight turnover is lower than that of rail due to shorter transport distances. Conveyor transport (oil and gas) played a significant role: in 2024, 299.8 million tons were pumped through conveyors with a freight turnover of 150.1 billion ton-kilometers. Maritime transport (the ports of Aktau, Kuryk) provided a small volume of 4 million tons in 2024, down from its peak in 2011 due to the redistribution of oil exports by other means. Air cargo is estimated at thousands of tons per year, and its contribution is insignificant, although the growth rate is high after 2020.

In this analysis, recalculating the indicators using the exchange rate to the US dollar at the time of data collection does not reflect the growth dynamics and has no analytical value; however, it is acceptable to use the exchange rate at the time of the study, since no cross-country comparison is conducted.

Table 1

Key indicators of the development of the logistics industry in the Republic of Kazakhstan for all modes of transport (including conveyor transport) for selected years

Indicators	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Growth rate, %
Cargo transported by all types of transport, million tons	662.2	657.9	762.4	840.8	869.9	851.1	910.5	927.2	999.2	1,090.0	164.6
Freight turnover of all types of transport, billion t-km	402.9	375.5	419.5	456.4	448.8	443.6	483.5	479.7	503.5	520.9	129.3
Number of places for simultaneous storage and warehousing	3236	2525	2451	2672	2698	2703	2913	2775	2806	4136	127.8

Thus, the obtained data indicate a comprehensive transformation of the country's transport and logistics industry. These include strengthening key transport segments, active expansion of domestic and transit logistics, and strengthening the role of service components.

#### 5.4. Analysis of digital transformation of the transport and logistics complex of the Republic of Kazakhstan

The e-commerce industry is considered a key area of application for intelligent logistics. In turn, the increase in e-commerce volumes will contribute to the accelerated development of the intelligent logistics segment. All this is happening due to rapid progress in the field of information technology and platform solutions, combined with an increase in the level of digital literacy of the population [6]. The development of e-commerce in the Republic of Kazakhstan in recent years has shown steady positive dynamics, reflecting general global trends in the digitalization of trade. E-commerce, which covers both retail sales of goods and the provision of services through digital channels, is becoming an increasingly important segment of the national economy. In Fig. 4, data for the period 2015–2024 allow to track quantitative changes in the volume of e-commerce, as well as to assess its share in the structure of the total volume of retail trade. Since all this serves as a basis for analyzing the effectiveness of government support measures for the digital economy and progress in the formation of digital infrastructure.

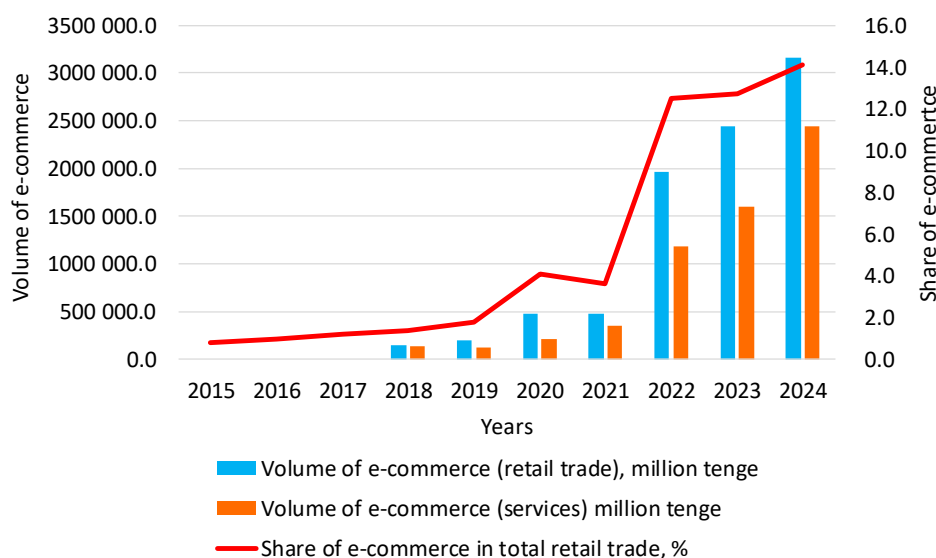


Fig. 4. Development of e-commerce in the Republic of Kazakhstan

Between 2015 and 2024, e-commerce volumes in the Republic of Kazakhstan increased tenfold in both the goods and services segments. Particularly significant growth has been observed since 2020, which is likely due to the accelerated digital transformation against the backdrop of the COVID-19 pandemic. The share of e-commerce in total retail trade increased from 0.8% in 2015 to 14.1% in 2024, reflecting growing consumer and business confidence in digital sales and interaction channels. These indicators confirm the need for further development of digital logistics, platform solutions and enhanced digital security measures aimed at the sustainable development of e-commerce in the Republic of Kazakhstan.

In recent years, the Republic of Kazakhstan has been focusing on the digital transformation of the transport and

logistics sector. The introduction of modern IT solutions is seen as a key factor in increasing the competitiveness of transit corridors and reducing costs. One of the achievements has been the creation of a single window for export and import operations. Since 2019, the Republic of Kazakhstan has been operating a national portal called 'Single Window', through which participants in foreign economic activity can submit all necessary documents online. At the same time, the customs information system was modernized: the Astana-1 automated system, based on the ASYCUDA platform, was introduced, enabling electronic cargo declaration and pre-clearance. As a result, the average time for customs clearance of imports has been reduced and the transparency of procedures has increased, as noted in the Doing Business rankings of previous years (Fig. 5).

Particular attention is paid to the digitalization of transit corridors in international cooperation. In November 2023, the Central Asian countries, within the framework of the UN Special Program for the Economy of Central Asia SPECA, adopted the "Roadmap for Digitalization of the Trans-Caspian Corridor". The Republic of Kazakhstan was included here, as it is aimed at standardizing the exchange of data between ports, railways and other participants in transportation. At the moment, electronic exchange of cargo data between the ports of Aktau and Baku has already been established. It is also planned to connect other nodes of the corridor to the common system – Kuryk, Turkish and Black

Sea ports, for end-to-end digital traceability of transit shipments. These measures simplify procedures, reduce border delays and lower corruption risks, thereby increasing the attractiveness of the routes.

Innovations are also affecting the field of domestic warehouse and transport logistics. The government has initiated the creation of 'smart' logistics centers with integrated warehouse management systems (WMS), sensors and IoT technologies for real-time cargo monitoring. In the Almaty region, a cluster focused on high-tech logistics solutions is being created in the Alatau innovative SEZ. According to the Astana International Financial

Centre [10], the Republic of Kazakhstan is implementing blockchain technologies to track supply chains and is testing the use of artificial intelligence to optimize delivery routes. These innovations are designed to reduce operating costs, speed up cargo processing and ensure high transparency of transit operations. The AIFC predicts that the digitalization of the industry will create thousands of new jobs for qualified specialists and drive growth in the share of logistics in GDP.

However, despite the progress, the level of digitalization of logistics in the Republic of Kazakhstan still lags behind leading countries. The Ishikawa diagram shown in Fig. 6 illustrates the main reasons for the low level of digital transformation of international trade in the Republic of Kazakhstan.

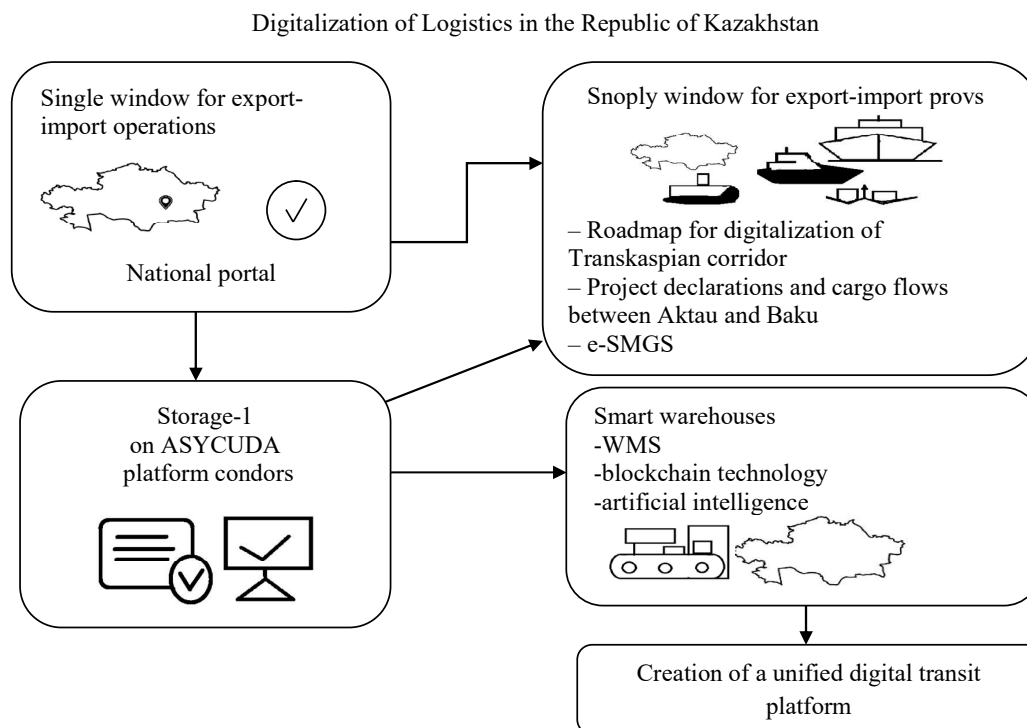


Fig. 5. Directions for the digitalization of the transport and logistics complex in the Republic of Kazakhstan

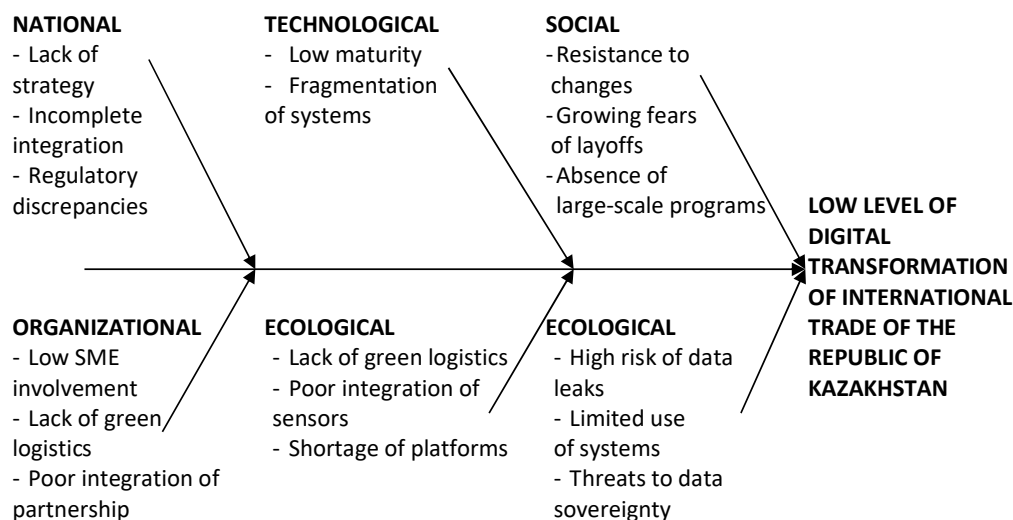


Fig. 6. Problems of digital transformation of logistics processes in Kazakhstan's international supply chains

The focus is on the lack of a coordinated state strategy covering the entire range of issues related to the digitalization of logistics and foreign economic activity. Despite the existence of initiatives such as Digital the Republic of Kazakhstan and the transport development program until 2030, their implementation is limited to sectoral projects. The problems are exacerbated by incomplete integration into international digital platforms (e.g., e-SMGS), discrepancies in digital document management standards with key trading partners, weak interagency coordination, and limited functionality of the national Single Window portal.

Thus, despite a number of successes achieved in the digitalization of the logistics industry, the Republic of Kazakhstan continues to face fragmentation of information flows. This is both duplication of logistics industry procedures and insufficient coordination between the systems of participants

in foreign economic activity. These problems are particularly relevant in the context of cross-border transport, which requires the rapid and reliable exchange of data between multiple links. In response to these challenges, global practice offers the concept of a “data conveyor” – a comprehensive methodology for building digital transport and logistics chains. It is based on the principles of preliminary aggregation, reusability and legal significance of logistics information. The implementation of this approach in Kazakh logistics appears to be a relevant direction for further reforms.

Fig. 7 illustrates the ‘data conveyor’ scheme in the supply chains of agricultural products involving the Republic of Kazakhstan within the framework of the ‘Eurasian Agro-express’ project. It is based on the idea of end-to-end digital tracking of cargo from the point of origin to the final recipient using a unified digital ecosystem.

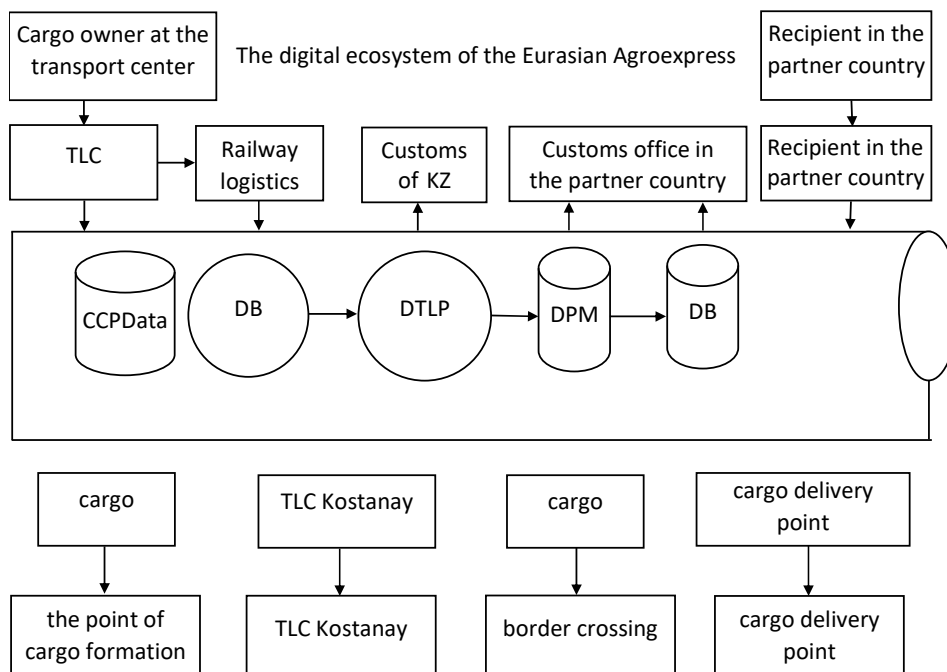


Fig. 7. Diagram of the 'data conveyor' in agricultural product supply chains within the framework of the Eurasian Agroexpress project

The starting point of the diagram is the shipper in the Republic of Kazakhstan, which ships products through one of the transport and logistics centers. The cargo is then transferred to a rail transport operator (in particular, KTZ Express), which provides transportation as part of a multi-modal route.

During the movement of the cargo, data on the consignment is generated in digital form (CCP Data) and transferred to a centralized logistics information repository (DB). The key element of the entire architecture is the digital transport and logistics platform (DTLP), developed as part of the Eurasian Agroexpress project and based on open source software principles. The platform aggregates data from various participants, validates it, compares it with regulatory requirements, and automatically routes it throughout the chain.

The legal significance and security of data are ensured by data management modules (DPM the Republic of Kazakhstan and DPM partner country). It is through these modules that compliance with e-document management standards is monitored, including e-Contract, e-SMGS, e-Invoice, e-Customs declaration, electronic phytosanitary and veterinary certificates. The architecture used allows for data exchange between national customs systems and external digital platforms of partners, including LOGINK, in the case of China, or similar national systems of other countries.

At the border crossing stage, all necessary information about the cargo is already available in digital form, which minimizes administrative procedures, reduces inspection times and ensures real-time traceability of the shipment. After crossing the border, the cargo is transported to the recipient country, where its digital tracking continues until it reaches its final destination – a distribution center or retail outlet.

Thus, the diagram demonstrates the implementation of the "data conveyor" methodology in the applied context of national logistics. Since the digital transport and logistics platform acts as an integrating link that ensures an end-to-end, standardized and legally significant flow of infor-

mation throughout the entire cross-border supply chain.

## 6. Results of the analysis and discussion of the institutional effects of digitalization of transport corridors in the Republic of Kazakhstan

The results of the study show that the development of the transport and logistics complex of the Republic of Kazakhstan in 2015–2024 was accompanied by a steady growth of the main indicators Table 1. The volume of transportation increased from 662.2 million tons in 2015 to 1090 million tons in 2024, and freight turnover reached 520.9 billion ton-km. At the same time, the structure of services by types of activity Fig. 3 and the dynamics of in-

come of transport companies Fig. 4 reflect a significant expansion of the rail, road and conveyor transport segments. It can also be noted that the digitalization of the transport and logistics complex is accompanied not only by an increase in freight turnover indicators Fig. 3, 4, but also by high-quality institutional transformations. The key element here is the introduction of the "data conveyor" methodology Fig. 7, which ensures end-to-end digital support of cargo flows.

For the Republic of Kazakhstan, the application of this methodology provides a number of functional and institutional effects:

1. Reduction of errors and duplication due to end-to-end digital access of all chain participants to a single mass data. As the experience of implementing the "Single Window" and e-SMGS pilot projects has shown, unification of information eliminates contradictions between departments and increases the coordination of actions.

2. Acceleration of logistics operations thanks to electronic declaration and digital data exchange between ports. In the EAEU pilot projects on e-CMR, the document processing time has been significantly reduced, which confirms the increase in the transit potential of the Republic of Kazakhstan.

3. Due to the transition to electronic document management, transaction costs are reduced: according to the EEC, the introduction of e-CMR allows saving up to 4.6 euros per consignment note [13]. An additional effect is provided by integration with WMS, which optimizes warehouse stocks.

4. The legal significance of the data is ensured by the recognition of electronic documents signed with an EDS in the Republic of Kazakhstan and partner countries [14, 15], which reduces regulatory risks and strengthens business confidence.

5. The anti-corruption effect is achieved by automating processes and minimizing contacts between foreign trade participants and government agencies, which makes the procedures transparent and accountable Table 1.

Compared with existing studies, which focus mainly on infrastructure modernization [10, 16-29], the obtained results



demonstrate the systemic benefits of digital transformation and the implementation of the “data conveyor” in logistics.

At the same time, the study has limitations: the quantitative assessment of the effects of digitalization is descriptive in nature and is based on aggregated statistical data Table 1. In addition, the methodology is applicable only under the condition of international harmonization of digital standards.

The disadvantages include the lack of econometric modeling of the impact of digital technologies on the indicators of time and cost of transportation. Further research should fill this gap by building simulation models and analyzing scenarios for the development of logistics corridors.

Development prospects are associated with the expansion of the application of the “data conveyor” methodology to related industries (agriculture, energy) and the integration of the Republic of Kazakhstan into global digital platforms (LOGINK, e-SMGS). Potential difficulties include the scale of big data processing, harmonization of legal norms and ensuring the cyber resilience of transit flows.

7. Conclusions

1. According to statistics, the conducted assessment of the infrastructure and digital development of the transport and logistics system of the Republic of Kazakhstan revealed a significant increase in transportation volumes – from 662.2 to 1,090 million tons and freight turnover – from 402.9 to 520.9 billion ton-km for 2015–2024. Unlike neighboring EAEU countries, the Republic of Kazakhstan demonstrates a more balanced combination of infrastructure modernization and digital services, which is explained by the priority role of transit routes, especially the “Middle Corridor”.

2. A comparative analysis of international indices (LPI, WEF, OECD) showed that the Republic of Kazakhstan lags behind the leading countries: the LPI indicator is 2.7 points against 4.3 for Singapore. The quality of infrastructure and cargo tracking remain limiting factors. Unlike countries with a high level of digital maturity, the Republic of Kazakhstan faces institutional barriers and legal inconsistency, which explains the slow growth rate of ratings.

3. Analysis of the dynamics showed an increase in freight traffic, warehouse capacity and sector revenues,

freight traffic growth increased by 64.6% and revenues of key segments doubled in 2015–2024. Unlike most countries in the region, the Republic of Kazakhstan demonstrates not only recovery from the 2020–2021 crisis, but also sustainable growth. This is due to the expansion of the domestic market, the development of e-commerce and the growth of transit.

4. The introduction of the “data conveyor” and e-CMR ensures faster procedures, lower costs (up to 4.6 euros per consignment note) and increased transparency. This is shown by a study of the digital transformation of the transport and logistics system of the Republic of Kazakhstan. It was revealed that the growth of e-commerce stimulated a doubling of road transport revenues, from 322.9 to 630.4 billion tenge in 2022–2024. All this shows the difference between the current stage of development and the previous ones, where the main driver was physical infrastructure.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript. Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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