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CONTENTS

SUPPLY CHAINS OF PERISHABLE AGRI-FOOD PRODUCTS IN THE EAEU: CONCEPTUAL APPROACHES AND DEVELOPMENT OF LOGISTICS INFRASTRUCTURE

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Abstract: The purpose of this study is to develop a conceptual approach to the formation of an integrated logistics platform for perishable agri-food products within the Eurasian Economic Union (EAEU). The methodological framework is based on systems and scenario analysis, SWOT assessment, comparative analysis of the logistics potential of EAEU member states, and modeling of logistics chain efficiency under different levels of integration using panel empirical data for the period 2015–2023. Selected indicators of logistics infrastructure are employed to provide a descriptive assessment of the current state of agrologistics as of 2023.

The modeling results demonstrate that coordinated investment policies and regulatory harmonization can significantly enhance the efficiency of agrologistics chains in the context of regional integration. The findings confirm that digitalization and the development of cold chain infrastructure are key determinants of logistics sustainability, while the coordination of regulatory and investment mechanisms substantially improves logistics efficiency across the EAEU member states. Based on the estimated parameters, a scenario-based forecast of agrologistics development up to 2030 is proposed. The study introduces a scalable model of an integrated agrologistics platform incorporating a cluster-based approach, a unified digital framework, and public–private partnership mechanisms adaptable to the specific conditions of EAEU countries. The scientific

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novelty of the research lies in substantiating a platform-based approach to cross-border agrologistics grounded in the synergy of digital and physical solutions, institutional coordination, and targeted infrastructure policy.

Keywords: agri-food products, cold chain logistics, logistics, infrastructure, digitalization, supply chain

JEL: O18, Q13, R42, F15, L91

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1.Introduction

The growing global emphasis on food security reinforces the importance of efficient supply chains for perishable agri-food products. Their reliable delivery is critical not only for product quality and economic sustainability, but also serves as the core of regional integration strategies (FAO, 2021). Within the EAEU, the problem is exacerbated by spatial, climatic and regulatory differences between the member countries.

Existing literature predominantly focuses on technical aspects (temperature control, transport efficiency) or economics at the national level (Kumar & Budin, 2006; Aung & Chang, 2014), ignoring cross-border institutional and infrastructural barriers. In contrast, the EU and ASEAN demonstrate efficiency through harmonized legal and digital systems (Rodrigue et al., 2016; Kampan, 2017). Current research highlights the need for holistic logistics models that take into account digitalization, resilience and institutional alignment, especially in the face of climate and geopolitical challenges (Ivanov & Dolgui, 2020). However, such models are rarely adapted to decentralized systems as in the EAEU.

This study proposes a conceptual model of an integrated EAEU agro-logistics platform that synthesizes digital, institutional and infrastructural elements into a single framework. Based on the theoretical framework of supply chain management (Christopher, 2016) and inter-organizational coordination (Zajac & Olsen, 1993), it is argued that digital interoperability, institutional alignment and strategic investments are critical for the sustainability of perishable goods logistics in the region.

A literature review on sustainable agro-logistics, digitalization and institutional coordination (Aung & Chang, 2014; UNEP & FAO, 2022; Hassini et al., 2012; Raimbekov et al., 2017; World Bank, 2023) highlights the need for a unified platform to improve the transparency and reliability of supply chains in the EAEU (Raimbekov et al., 2017).

The proposed model includes institutional mechanisms, digital traceability and infrastructure clusters, providing an adaptive, sustainable and integrated logistics system.

The key research question is: how can EAEU build a coherent and sustainable logistics network for perishable products that ensures economic integration and food security of the region? To address this objective, the study sets the following tasks: (1) analyze current logistics systems in the EAEU member states and identify bottlenecks and development opportunities in the cold chain infrastructure; (2) assess sustainability factors and scenarios of agro-logistics development until 2030, (3) identify investment priorities (4) develop a model of the EAEU integrated logistics platform.

2. Methodology

The methodological framework of this study integrates both qualitative and quantitative approaches to assess the resilience and efficiency of perishable agri-food logistics across EAEU member states. The research employs a combination of systematic literature review, statistical data collection, semi-structured expert interviews, SWOT analysis, and econometric modeling.

The empirical component includes interviews with 15 experts from all EAEU countries—comprising representatives from logistics businesses, government agencies, and industry specialists—which enabled the identification of institutional barriers and region-specific characteristics of agro-logistics development. SWOT analysis was applied to evaluate country-level strengths, weaknesses, opportunities and threats.

Selected tables reflect the state of agrologistics infrastructure as of 2023 and are used for a descriptive assessment of the current level of development, whereas the econometric analysis is based on data for the period 2015–2023.

The econometric model is based on multiple linear regression, where the dependent variable is an integrated logistics efficiency index (Y) capturing the reliability, speed and adaptability of supply chains. Independent variables include the level of logistics digitalization (X_1), cold storage capacity per capita (X_2), the logistics infrastructure index (X_3) (World Bank, 2023), the volume of logistics-related investments (X_4) (Eurasian Economic

Commission [EEC], 2021), and the share of intra-union trade (X_5; Eurasian Economic Commission [EEC], 2023).

Scenario analysis explores three development trajectories through 2030: a baseline (business-as-usual), an integration-driven (enhanced coordination), and a technology-driven (prioritizing digitalization and sustainability) scenario. It accounts for political, economic and climatic factors, as well as international recommendations on sustainable cold chains (UNEP & FAO, 2022; Burnasov et al., 2020).

The conceptual model was developed using a systems approach and aims to establish an integrated logistics platform for the EAEU by unifying digital, institutional, and infrastructural components (Hassini, 2012; Christopher, 2016). The methodology specifically considers the decentralized institutional structure of the EAEU, distinguishing it from most existing studies focused on more standardized integration blocs such as the EU or ASEAN (Aung & Chang, 2014; Burnasov et al., 2020).

3. Results of the study

3.1 Logistics infrastructure of EAEU countries: current state and limitations

Analyses of EAEU logistics indicators (in terms of LPI, cold infrastructure and total logistics base) revealed significant disproportions in institutional, digital and infrastructure development (Tables 1-3), which causes heterogeneous conditions for sustainable supply chains of perishable products.

Table 1.
Logistics performance of EAEU countries by LPI sub-indices, 2023

Country	Rank	Score	C	I	IS	CL	T&T	TML
Kazakhstan	79	2.7	2.6	2.5	2.6	2.7	2.9	2.8
Russia	88	2.6	2.4	2.7	2.3	2.6	2.9	2.5
Belarus	79	2.7	2.6	2.7	2.6	2.6	3.1	2.6
Armenia	97	2.5	2.5	2.6	2.2	2.6	2.7	2.3
Kyrgyzstan	123	2.3	2.2	2.4	2.4	2.2	2.4	2.3
Average	–	–	2.46	2.58	2.58	2.42	2.54	2.80

Note: compiled based on (World Bank, 2023), where T – Customs, I – Infrastructure, ***IS*** *– International Shipments, CL – Logistics Competence, T&T – Tracking and Tracing, TML – Timeliness.*

Table 1 reveals that Kazakhstan and Belarus lead the EAEU in terms of logistics infrastructure development, demonstrating the highest scores across key indicators. Armenia stands out for its relatively high technological adoption despite weaker overall logistics performance. Russia shows average results, while Kyrgyzstan significantly lags behind in all components. These disparities suggest the need to strengthen service quality, foster technological integration, and enhance supranational coordination to improve the efficiency of perishable goods supply chains across the Union.

Table 2 presents an assessment of cold chain infrastructure deficits and identifies key barriers to its development in each member state.

Table 2
Cold Chain Coverage in EAEU Countries, 2023 (% of Demand)

Country	Cold storage capacity (thousand tons)	Estimated deficit (%)	Key barriers
Russia	7,500	15%	Ageing infrastructure
Kazakhstan	1,200	35%	Lack of investment
Belarus	1,800	20%	Tariff policies
Armenia	450	50%	Geographic constraints, high energy consumption
Kyrgyzstan	300	60%	Absence of rural storage facilities

Source: Data on cold storage capacity and logistics barriers for 2023 are based on an analysis of national and regional logistics strategies of EAEU member states, as well as reports by international organizations (FAO, World Bank).

The assessment of cold chain logistics coverage in the EAEU countries reveals pronounced disproportions (Table 2). Russia has the largest capacity (7.5 million tonnes), where the deficit is 15%, but development is constrained by deteriorating infrastructure. Kazakhstan demonstrates a significant gap (35%) against the background of limited investment inflow. In Belarus, despite a moderate deficit (20%), tariff policy remains the main constraint. Armenia and Kyrgyzstan have the most acute deficits (50% and 60% respectively), due to geographical fragmentation, energy intensity and lack of storage facilities in rural areas. These factors highlight the need for targeted logistics modernization, taking into account national conditions and barriers.

A comparative analysis of logistics digitalization in the EAEU countries shows that Russia (65%) and Belarus (58%) lead the way in implementing digital solutions such as automation, digital routing and supply chain management. Kazakhstan (45%) shows moderate progress with high growth potential, while Armenia (30%) and Kyrgyzstan (25%) lag significantly behind, especially in terms of IoT, blockchain and digital platform adoption.

Accelerating digital transformation in the EAEU requires differentiated support for less developed countries - through investments, infrastructure measures and adaptation of external IT solutions to regional specifics. For spatial analysis of the logistical accessibility of agro-food flows in the EAEU, a cartogram of agro-logistic hubs was developed, classified into central (Moscow, Minsk, Almaty), local (Yerevan, Bishkek) and potential (Karaganda, Osh, Gyumri) based on infrastructure development, institutional connectivity and role in interstate supply chains. The analysis has shown the need for targeted upgrading of local centers and support for prospective nodes, which will diversify routes, enhance regional connectivity and improve the sustainability of supply chains.

Comparative analysis of the logistics infrastructure of the EAEU countries (Table 3) revealed institutional advantages and infrastructural constraints hindering the development of agro-logistics.

Table 3

Results of the Analysis of Logistics Infrastructure Indicators in EAEU Countries, 2023

Indicator	Russia	Kazakhstan	Belarus	Armenia	Kyrgyzstan
Cold Storage Capacity (thousand m^3)	12,000	3,500	2,000	450	300
Logistics Performance Index (LPI)	2.6	2.7	2.7	2.5	2.3
Road Network Quality (scale 1–7)	3.1	2.8	3.6	2.4	2.2
Digital Tracking Infrastructure (out of 10)	7.5	5.0	6.5	4.0	3.5

Source: Compiled by the author based on data from the World Bank (Logistics Performance Index, 2023), FAO, the Eurasian Economic Commission, and national statistical agencies

Russia and Belarus are leading the way with developed cold and digital infrastructure, while Kazakhstan needs modernization and Armenia and Kyrgyzstan need to overcome systemic barriers. Improving efficiency requires coordinated integration policies to address imbalances and strengthen supply chain resilience.

The SWOT analysis confirms the heterogeneity of logistics development in the EAEU: the strengths of individual countries (geopolitical position, agricultural potential, market access) are combined with common challenges such as lack of cold storage capacity, digital solutions and regulatory coherence. However, there are prospects for sustainable growth through digital transformation and the development of regional logistics clusters.

These results form the basis for targeted national policies and harmonized integration mechanisms to address logistics imbalances and increase the resilience of agri-food chains in the EAEU.

Effective development of agro-logistics in the EAEU requires a coherent integration strategy focused on the expansion of cold chain infrastructure, digitalization and institutional harmonization. The key conditions are investment coordination, development of logistics corridors taking into account regional demand and activation of PPP mechanisms, which ensures the formation of a sustainable and adaptive logistics system of the Union.

3.2 Sustainability factors and scenarios for agro-logistics development

The empirical assessment of agrologistics sustainability factors in EAEU countries is based on panel data, which makes it possible to capture the dynamics of key indicators and smooth the effects of short-term shocks. The use of a multi-year time horizon ensures the robustness of correlation and regression analyses and enhances the reliability of scenario-based estimates. Correlation analysis based on panel data for the period 2015–2023 revealed a strong positive relationship between the sustainability of logistics chains and factors such as digitalization (r = 0.85), the level of infrastructure (r = 0.79), and the logistics performance index (LPI, r = 0.88). The resulting regression equation has the following form:

$$Y = 12{,}3 + 0{,}34 \cdot X_1 + 0{,}29 \cdot X_2 + 0{,}41 \cdot X_3 + 0{,}18 \cdot X_4 + 0{,}14 \cdot X_5 + \varepsilon$$

The multiple linear regression model ($R^2 = 0.89$, $p < 0.05$) confirms the statistical significance of all included variables. Logistics infrastructure exerts the strongest influence on the dependent variable, followed by digitalization, underscoring the critical role of transport accessibility and digital technologies in supply chain resilience. The impact of investment and integration variables also proves significant, highlighting the necessity of a coherent logistics policy at the EAEU level.

To assess the efficiency of agrologistics for perishable agri-food products in EAEU countries over the medium-term time horizon, a multiple regression model was developed incorporating the key determinants (X_1–X_5). Based on these parameters, three development scenarios were developed: inertial, integration-driven, and technological—each differing in digital maturity, institutional coordination, and investment dynamics.

The estimated coefficients of the regression model, based on data for the period 2010–2023, were used to construct a scenario-based forecast of agrologistics development in EAEU countries up to 2030.

Simulation results indicate that the highest values of the composite logistics index are achieved under the scenario that combines digital transformation with infrastructure modernization, confirming the strategic value of a coordinated approach to agro-logistics development in the EAEU (Table 4).

Table 4

Scenario-Based Forecast of Logistics Efficiency in the EAEU up to 2030 (Integrated Index Y)

Scenario	Digi-talisation (X_1)	Cold Chain Capacity (X_2)	LPI Growth (X_3)	Investment (% of GDP) (X_4)	Intra-EAEU Trade Share (X_5)	Projected Integrated Index (Y)
Baseline (Status Quo)	+10%	+15%	+0.2	1.2%	22%	0.598
Integration (Moderate)	+25%	+35%	+0.5	1.8%	30%	0.726
Technological Breakthrough	+40%	+50%	+0.9	2.5%	38%	0.831

Note. Figures for 2024–2030 are authors' forecasts/estimates. Source: Authors' calculations based on data from the Eurasian Economic Commission (2023a, 2023b)

The ‘technology leap’ scenario shows the best sustainability and efficiency indicators, emphasizing the role of digitalization, cold chain development and active investment policies.

According to calculations, the Status Quo scenario has a logistic efficiency index of 0.598, reflecting fragmented systems and limited interstate interaction.

Moving to the Moderate Integration scenario, which includes standardization, targeted investment and partial digital transformation, leads to an increase in the index to 0.726. The highest efficiency (0.831) is achieved in the deep integration scenario, which provides for the coordination of infrastructure solutions, the formation of a unified digital environment and institutional convergence.

Thus, the modelling results confirm the key dependence of the efficiency of EAEU agro-logistic systems on the degree of digital maturity, infrastructural coherence and institutional coordination. Deep integration forms the basis for sustainable logistics chains, reduces losses and contributes to the creation of a unified agri-food environment in the region.

3.3 Investment priorities and integration effects

The analysis of investment strategies of the EAEU countries and international recommendations (United Nations Environment Programme & Food and Agriculture Organization of the United Nations [UNEP & FAO], 2022) allowed to identify priority areas for sustainable development of agro-logistics and improving the efficiency of supply chains of perishable goods. The main areas are the expansion of the cold chain, digitalization of logistics processes, modernization of cross-border infrastructure, development of agro-logistics clusters and strengthening of public-private partnership mechanisms. Modernization of cold chain infrastructure will reduce losses and extend the shelf life of products, while digitalization through IoT, blockchain and sensor systems will increase traceability and reduce transaction costs. Upgrading customs terminals and streamlining procedures will accelerate cross-border trade, while agro-logistics clusters will promote SME development and regional economic activity. Involvement of private capital through PPPs will ensure sustainable financing and improved operational efficiency.

In the short term (2024–2026), the development of the cold chain delivers the greatest impact; in the medium term (2026–2030), sustainable outcomes are achieved through the implementation of digital technologies, while the long-term multiplicative effect is generated by the development of agrologistics clusters and public–private partnership mechanisms. The main barriers, such as infrastructural and digital asymmetry, lack of unified standards and limited interstate coordination, require a transition to a single integrated logistics platform based on a network of agro-logistics clusters, a single digital infrastructure (IoT, blockchain, AI) and harmonization of regulatory requirements (packaging, labelling, temperature control). The most important implementation mechanism remains public-private partnership, which will create a coordinated and technologically advanced logistics system in the EAEU.

3.4 Model of an integrated logistics platform

The conceptual model of an integrated agro-logistics platform of the EAEU is a framework for the formation of a unified digital-physical infrastructure that ensures efficient processing and cross-border movement of perishable agro-food products. The model includes institutional and technological levels, integrating national logistics nodes into a common

Eurasian network. Its architecture is based on digitalization (IoT, blockchain), synchronization of cold chains and harmonization of regulations between participating countries, which allows for the formation of an adaptive and compatible ecosystem (Figure 1). Integration of digital and physical infrastructure, institutional interoperability of standards and consideration of regional specificities contribute to reducing losses and costs, increasing supply sustainability and investment attractiveness.

The model creates a basis for the development of high value-added logistics services, interstate co-operation and increased regional trade.

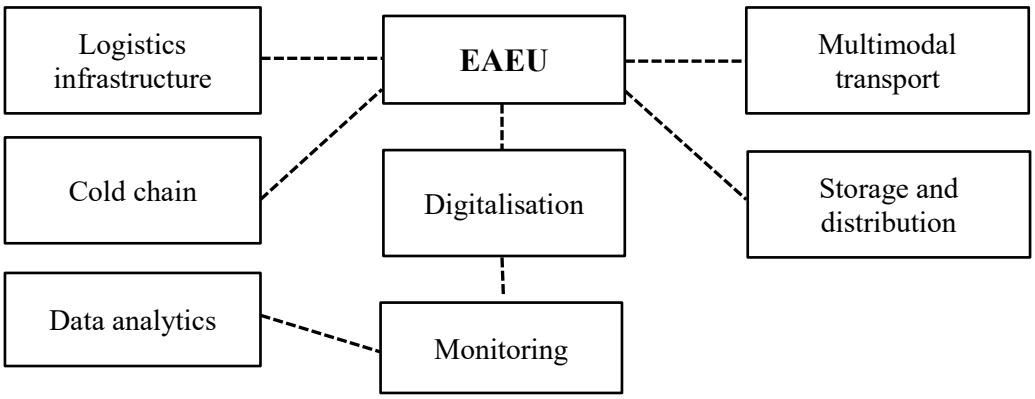

Figure 1. Model of the EAEU integrated logistics platform
Source: Compiled by the authors

The integrated development of agro-logistics in the EAEU requires taking into account the differences in infrastructure and the level of digital maturity of the countries (Raimbekov et al., 2023). For states with a predominance of small farms (Armenia, Kyrgyzstan), agro-logistics clusters are a priority, while digitalization and regulatory harmonization are the main factors of transformation. The development of a single digital platform, the EAEU AgriLogistics Hub, ensures transparency, adaptability and sustainability of supply chains.

The model includes intergovernmental coordination, environmental solutions and involves a governance framework, investment support, competence development and the use of IoT, blockchain and AI technologies.

Simulations show that synchronized investment and digital harmonization significantly improve logistics performance. Underestimated advantages of individual countries, such as Kazakhstan, were identified, and the impact of infrastructure modernization was higher than expected.

The novelty of the model lies in the end-to-end cross-border integration of digital and physical logistics, which was previously limitedly addressed in the academic literature (Palazzo & Vollero, 2022; Bandaranayake et al., 2024). The presented results confirm the feasibility of platform solutions and the need for a supranational agro-logistics strategy in the context of regional integration.

Conclusion

The study confirmed the key role of logistics in ensuring the sustainability of agri-food chains in the EAEU. Digitalization and the development of cold infrastructure act as the main drivers of efficiency improvement, demonstrating a high correlation with logistics maturity. Scenario analysis has shown that the maximum effect is achieved when implementing a strategy of technological transformation based on digital integration, regulatory harmonization and coordinated investments. At the same time, institutional barriers and cross-country disparities remain significant challenges.

The developed conceptual model of the EAEU agro-logistics platform offers an adaptive solution to these problems through the development of clusters, digital services and PPP mechanisms. Its implementation requires coordinated policy, priority investments and large-scale digitalization, which will ensure the sustainability and competitiveness of regional agro-logistics.

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