

**BEYOND THE BELT AND ROAD: INTEGRATED AUTONOMOUS
SYSTEM FOR TRANS-EURASIAN LOGISTICS:
CONCEPTUAL ANALYSIS AND VISION FOR THE FUTURE OF RAIL
TRANSPORT**

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Key words: rail transport, Trans-Eurasian logistics corridor, Integrated multimodal system, AI in logistics, supply chain security, sustainable transport, economic integration, Rail-on/rail-off (RoRo), viaduct infrastructure, neo-structural realism.

Abstract: This article presents a revolutionary concept for the future of rail transport viewed as a fully autonomous corridor. It is designed as an integrated system of infrastructure, technology, and logistics that promises to reduce delivery times between China and Europe by over 50% – from the current 30–40 days by sea to 15 days via a fully autonomous digital corridor. The essence of the concept lies in the creation of a pilot high-speed, safe, and energy-efficient rail corridor connecting Western China (Xinjiang) by land through Kazakhstan to Central Europe. The potential route passes through maritime and river transit points: Aktau (Kazakhstan), Baku (Azerbaijan), Poti (Georgia), Varna and Ruse (Bulgaria), with a final destination in Budapest (Hungary) and a branch to Belgrade (Serbia). The proposed concept represents a technological innovation based on three interconnected elements. The first is the infrastructure – a viaduct built from precast concrete segments, ensuring rapid assembly, minimal land use, high physical security, and a minimal environmental footprint. The second element comprises the means of transport – autonomous robotic electric platforms designed to carry standard containers with their own navigation systems. The system is managed by a Distributed Command and Control System (DCCS). The concept offers high material flow speed, predictability, physical security, reduced operating costs, and a lower carbon footprint, while simultaneously providing a strong stimulating effect on the economies along the route.

JEL Classification: L92, R41, O33, F50.

1. INTRODUCTION

The motives for developing this conceptual framework are based on the author's long-standing research and teaching activities in the field of global transport and logistics development. The immediate stimulus for formulating this vision was an interview with MP Tsoncho Ganev regarding his participation in a meeting with the First Vice Premier and Minister of Transport of China in Xi'an (Dnevni, 2025). This discourse clearly outlines not

only the interest of the Chinese side but also the main structural obstacles to the development of transport connectivity in the Republic of Bulgaria. The present concept represents an answer to the question "What is to be done?" and is a synthesis of principles from modern logistics and transport technologies. It builds upon the established advantages of Short Sea Shipping (Paixão & Marlow, 2002; Yotsov, 2017; Maliszewska & Van Der Mensbrugghe, 2019), radically rethinking them by applying the principles of autonomy and continuity of material flow (Frazelle, 2002; Bogue, 2024). The system's management is inspired by the Logistics 4.0 paradigm and digital supply chains (Winkelhaus & Grosse, 2020; Ivanov, Dolgui & Sokolov, 2019), while the infrastructure design is grounded in principles of sustainability and rapid construction (Wang & Adeli, 2014). Thus, the document offers not merely an alternative model of a multimodal transport corridor, but an innovative architecture aimed at overcoming the systemic deficiencies of existing Eurasian transport corridors.

The primary economic effect is expressed in reducing transit time to 15 days. Expected benefits also include a significant reduction in operating costs, improved supply chain security, and a reduction in the carbon footprint. The project has the potential to become a model for transforming the entire Eurasian logistics landscape into a unified network structure. Additionally, it could have a tremendous stimulating effect on the economic development of the countries along the route by creating jobs in both the implementation and operational phases. The scale of the project requires attracting investment, which will also create positive development dynamics. Implementation should proceed in stages, starting with pilot projects demonstrating economic efficiency and technical feasibility, followed by gradual expansion to the remaining parts of the route. The practical realization of the concept requires the creation of an international consortium, and the scale and heterogeneity of the stakeholders necessitate the development of innovative public-private partnership models.

2. RESEARCH METHODOLOGY AND COMPARATIVE ANALYSIS

This study applies a complex methodological approach, integrating the hypothetico-deductive method for modeling transport systems with an in-depth comparative economic analysis of existing logistics chains. The main research task is to deconstruct structural inefficiencies and identify critical bottlenecks in conventional corridors – the Northern (via Russia), the Middle (Trans-Caspian), and the Maritime (via Suez). The goal is not merely optimization, but the proposal of a new architectural paradigm to overcome them.

Detailed comparative analysis reveals systemic deficits in the current global logistics map:

- **The Southern Sea Route:** While economically most advantageous for mass cargo with low added value, this route suffers from significant time inefficiency (30-45 days transit time). It is heavily dependent on "slow steaming" practices to save fuel (Maliszewska & Van Der Mensbrugghe, 2019) and exhibits extreme geopolitical vulnerability at strategic choke points such as the Bab el-Mandeb Strait, the Strait of Malacca, and the Suez Canal.

- **The Northern Rail Corridor:** Historically preferred for its speed compared to maritime transport, it is currently compromised by high geopolitical risk. Sanction regimes, insurance impossibilities, and uncertainty caused by the war in Ukraine make it an unattractive option for Western logistics operators.

- **The Current "Middle Corridor" (TITR):** Despite growing interest, this route suffers from severe multimodal fragmentation. The need for multiple container transshipments between trains and ferries drastically increases both the service cost and the risk of cargo damage (Yotsov, 2017).

Table 1. Comparative Matrix of Trans-Eurasian Logistics Corridors

Feature	Southern Sea Route	Northern Rail Corridor	Conventional Middle Corridor (TITR)	Proposed Autonomous System
Transit Time (China-EU)	30-45 Days	18-22 Days	20-30 Days	~15 Days
Cost Efficiency	High (Low cost)	Medium	Low (High handling costs)	High (Low OpEx)
Geopolitical Risk	High (Choke points)	Critical (Sanctions)	Medium (Coordination)	Low (Institutionalized)
Carbon Footprint	High (Heavy Fuel Oil)	Medium	Medium	Zero/Low (Electric)
Reliability	Variable (Weather/Port congestion)	Low	Low (Bottlenecks)	High (Autonomous)

The proposed concept directly addresses these structural deficits by eliminating physical transshipment through the introduction of RoRo/Rail-on-Rail-off technology and full autonomy of the rolling stock. This theoretically allows for maintaining a constant average speed and a 24-hour continuous operating mode.

3. ROUTE AND LOGISTICS ARCHITECTURE

The transcontinental route is designed to minimize logistics obstacles and maximize efficiency by combining optimal land and water routes. The main logistics chain follows the sequence: Land → Sea → Land → Sea → Land → River/Land.

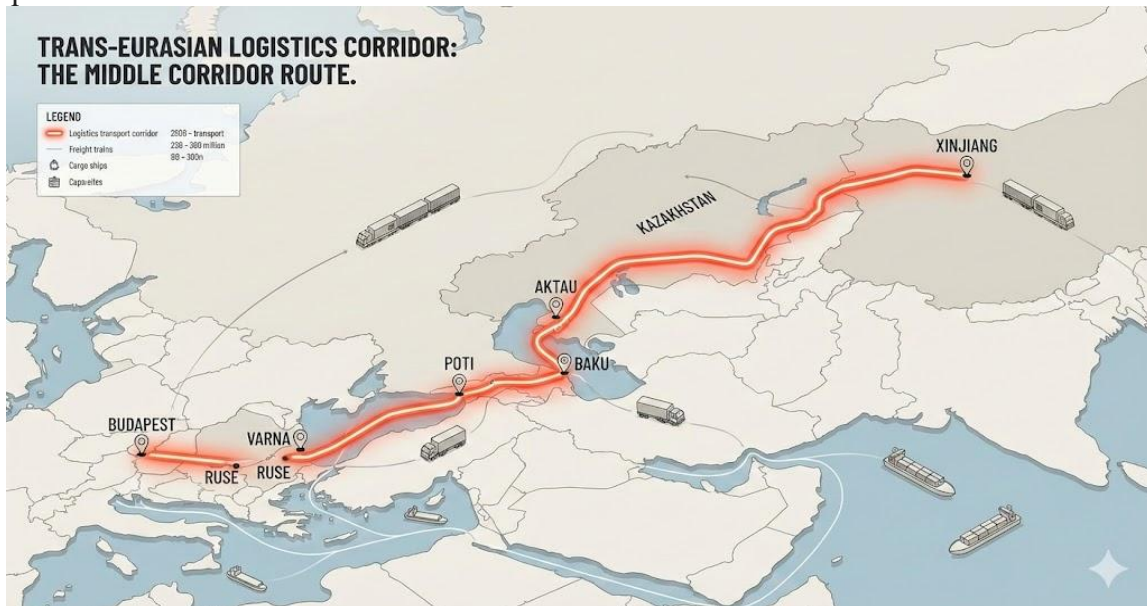


Fig. 1. Proposed Route Map – Xinjiang-Aktau-Baku-Poti-Varna-Ruse-Budapest.

[Source: Author's concept, visualized using 'gemini 2.5 flash image preview' AI generation model]

The specific trajectory covers movement from Western China (Xinjiang) to Aktau, Kazakhstan, followed by maritime transit across the Caspian Sea to Baku, Azerbaijan, and a land transition through the Caucasus to Poti, Georgia. The Black Sea segment connects Poti

with Varna, Bulgaria, from where the route continues to the multimodal hub in Ruse. From this strategic point, the flow branches in three directions: river transport along the Danube to Budapest (Hungary) and Belgrade (Serbia), as well as a northern land branch to Romania, Slovakia, and Poland.

The main logistics nodes – Aktau, Baku, Poti, Varna, and Ruse – utilize the Short Sea Shipping concept as a connecting link in the rail infrastructure (Yotsov, 2017). Specialized RoRo (Roll-on/Roll-off) ferries are used to transport the autonomous rail vehicles (Paixão & Marlow, 2002). Border formalities are minimized through pre-established intergovernmental agreements between participating countries for a single customs zone and integrated cargo tracking systems.

4. TECHNICAL AND TECHNOLOGICAL SPECIFICATIONS

The innovation of the proposed model lies in the radical change of the physical infrastructure and rolling stock.

Infrastructure (Viaduct):

The construction is based on standardized, factory-produced reinforced concrete sections mounted on pylons ranging from 5 to 12 meters in height (Wang & Adeli, 2014). This industrial construction method allows for parallel work at multiple points along the route, guaranteeing high quality and drastically reduced construction timelines.



Fig. 2. Conceptual Visualization of the Modular Viaduct System traversing diverse terrain (mountains, rivers, and plains).

[Source: Author's concept, visualized using 'gemini 2.5 flash image preview' AI generation model]

Elevating the track ensures complete isolation of the transport flow from ground traffic, animals, and people, eliminating the need for expensive tunnels, overpasses, and guarded crossings. This solution not only guarantees unprecedented physical security against sabotage and accidents but also allows for overcoming complex terrain features with gentle gradients.

Rolling Stock (Autonomous Platforms):

Instead of conventional heavy locomotives, the system uses individual robotic platforms (Smart Rail Bogies) (Bogue, 2024). Each unit is designed to carry one standard 40-foot container or two 20-foot containers, featuring its own electric propulsion. The platforms operate on the principle of "swarm intelligence" and communicate with each other via the Distributed Command and Control System (DCCS). This allows them to move in dense aerodynamic groups ("platooning"), reducing air resistance.

Cybersecurity and Resilience:

Given the fully digital nature of the DCCS, the system incorporates blockchain-based ledger technology for immutable cargo tracking and command authentication. This ensures resilience against cyber-attacks and spoofing attempts. The decentralized nature of the "swarm" logic also means that a compromise of a single node (platform) does not jeopardize the integrity of the entire network.

5. LOGISTICS NODES AND INTEGRATION

The system is based on a network of specialized logistics hubs that function not only as "gateways" between different stages but also as "intelligent switches" for the flow of goods (Winkelhaus & Grosse, 2020). Each of these key points performs three main roles: Gateway (intermodal connection), Switch/Distributor (dynamic routing), and Service Node (diagnostics).

In maritime corridors with integrated rail infrastructure, the traditional concept of shipping is radically reimagined. Instead of multiple loading and unloading of containers, entire rail cars transport themselves via Rail-on/Rail-off (RoRo) technology. This eliminates the most labor-intensive stage in conventional logistics – loading and unloading activities, preserves cargo integrity, and reduces the transfer process from days to minutes (Frazelle, 2002).

6. GEOPOLITICAL DIMENSIONS AND NEO-STRUCTURAL REALISM

From the perspective of international relations and neo-structural realism, this project transcends the boundaries of a conventional commercial venture, functioning as a strategic instrument for geopolitical balancing. In an era where economic coercion (weaponization of interdependence) is becoming the norm, the creation of an autonomous, physically secure, and legally integrated cargo transit zone generates a qualitatively new type of "structural interdependence" among participating states (China, Kazakhstan, Azerbaijan, Georgia, Bulgaria, Hungary) (Maliszewska & Van Der Mensbrugge, 2019).

Unlike traditional alliances based on military security and containment, here security stems from the continuity and reliability of the material flow. A key element in this architecture is the delegation of partial sovereignty over the corridor itself through supranational management exercised by the DCCS. This effectively creates a form of "algorithmic governance" that minimizes the risk of unilateral political actions. For Bulgaria, positioning the Varna-Ruse axis as a key "Gateway State" shifts the country's strategic weight from the periphery to the functional core of European logistics.

7. CHALLENGES AND CONCLUSION

Political challenges represent the most serious obstacle to the project's realization. Its construction affects the economic and geopolitical interests not only of transit states but also of global players like Russia, the USA, and the EU. Political coordination between countries with different legal systems requires the creation of an innovative legal and institutional framework. The presented concept offers a fundamentally new approach to rail transport, combining innovations in infrastructure and management. It has the potential to restructure Eurasian logistics and create a sustainable alternative to existing routes.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

During the preparation of this work, the author used the "Nano Banana" artificial intelligence model in order to generate conceptual visualizations (Figure 1 and Figure 2). After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Note: This text is prepared as a basis for strategic discussion and is subject to further analysis. All ideas are the author's.

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