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GREEN LOGISTICS AND CARBON FOOTPRINT REDUCTION IN TRANSREGIONAL TRANSPORT: INSIGHTS FROM THE MIDDLE AND ZANGEZUR CORRIDOR

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Abstract.
This study examines strategies for reducing the carbon footprint in transregional transport within international trade, with a focus on the Middle and Zangezur corridors. It explores how institutional frameworks, technological solutions, and infrastructure development shape the transition to low-carbon logistics. The analysis is based on content analysis of international reports, industry data, and statistical sources, combined with comparative and institutional approaches. Particular attention is given to digitalisation, multimodal transport, and infrastructure modernisation. The synthesis of secondary evidence indicates that emission reduction depends not only on infrastructure capacity but also on coordination, digital tools, and the integration of climate requirements into logistics operations. The comparative analysis suggests that the Middle Corridor may support multimodal and energy-efficient transport, whereas the Zangezur Corridor is associated with shorter routes and lower reported emission levels. Azerbaijan's integration into digital transit systems improves transparency, lowers transaction costs, and supports the development of green corridors. The transition to low-carbon logistics is shaped by the interaction of institutional coordination, technological change, and policy alignment. Rather than generating primary empirical data, the study develops a comparative analytical framework for interpreting secondary evidence. The results may inform national decarbonisation strategies and the development of sustainable transport corridors, particularly in Eurasia.

Keywords:
Trans-Caspian route; multimodal chains; digital transit systems; decarbonisation; greening of logistics

Introduction

The acceleration of climate change, stricter environmental requirements, and growing demand for low-carbon solutions increase the pressure on transport and logistics systems. International supply chains are forced to adjust infrastructure and management practices to reduce emissions, improve energy efficiency, and remain competitive. In this context, sustainable economic mechanisms are central to the long-term viability of logistics in international trade.

The increasing complexity of global transport brings a number of constraints, including ageing infrastructure, the high carbon intensity of major corridors, and uneven adoption of cleaner technologies. Energy price volatility, route disruptions, and institutional differences between trading partners further complicate the transition to low-carbon solutions. As a result, companies and governments are seeking ways to balance economic efficiency with environmental commitments.

These challenges are particularly visible in transregional transport corridors, where infrastructure constraints, regulatory differences, and environmental requirements intersect. Such corridors provide a useful context for examining how decarbonisation measures are implemented in practice and how they may influence logistics efficiency and environmental performance.

The objective of this study is to assess sustainable economic mechanisms of green logistics and examine strategies for reducing the carbon footprint in transregional transport, with a focus on the Middle and Zangezur corridors. To address this objective, the study focuses on two research questions: (1) how do institutional and technological factors support the decarbonisation of transregional transport corridors, and (2) how may digitalisation, multimodal transport, and infrastructure

development contribute to reducing the carbon footprint of the Middle and Zangezur corridors? The analysis explores institutional and technological drivers of decarbonisation, examines how environmental requirements can be balanced with logistics efficiency, and assesses the role of digital and infrastructure solutions in reducing emissions. The study adopts a qualitative analytical approach based on the synthesis and comparative interpretation of secondary data.

This article is presented as a qualitative analytical study based on the synthesis and comparative interpretation of secondary evidence rather than as an original empirical investigation. It combines content analysis of international reports, statistical sources, and scholarly literature with comparative and institutional approaches to examine the development of low-carbon transport corridors. The study interprets and synthesises existing evidence within a structured analytical framework.

The originality of the study lies not in generating new empirical measurements but in developing a comparative analytical framework that integrates institutional, technological, and infrastructure dimensions of low-carbon logistics. By examining the Middle and Zangezur corridors together, the study highlights different mechanisms and pathways of transport decarbonisation and contributes to a better understanding of how digitalisation, multimodal transport, and policy coordination interact within transregional logistics systems.

Literature Review

Recent research on green logistics points to the importance of institutional frameworks, technological change, and investment in low-carbon infrastructure for the transition to more sustainable transport systems (Rastegardehbidi and Su 2025). Digitalisation and changes in supply chain management are increasingly part of long-term corporate strategies, while global regulatory initiatives continue to influence the pace of decarbonisation.

Many studies associate green transport corridors with stakeholder coordination, technological modernisation, and infrastructure development, while digital platforms and monitoring systems are increasingly viewed as instruments for improving transparency, reducing transaction costs, and supporting more efficient transport operations (Jugovic et al. 2025; Borojo and Weimin 2025; Rentschler et al. 2025).

Regional studies also associate infrastructure investment and green technologies with stronger trade connectivity and lower-emission transport systems (Samadova et al. 2025; Osman et al. 2022). Overall, the literature suggests that green logistics depends on the interaction of technological, economic, and regulatory measures (Garg et al. 2025; Sevinç Başol et al. 2025).

At the same time, important gaps remain. Comparative evidence on transregional transport corridors is still limited, particularly regarding the interaction

between institutional coordination, digitalisation, and infrastructure development in supporting lower-carbon logistics. The long-term environmental effects of these measures also require further investigation.

Methodology

The study primarily covers the period from 2020 to 2025, a time of tighter climate regulation and growing digitalisation in transport systems, while also referring to selected recent developments where relevant. The analysis focuses on the Middle (Trans-Caspian) and Zangezur corridors, with particular attention to Azerbaijan, as these routes illustrate how low-carbon solutions are taking shape in transregional logistics.

The study employs a qualitative analytical design based on comparative and institutional analysis. It does not generate primary empirical data but interprets and synthesises secondary evidence from scholarly publications, international reports, industry data, and statistical sources.

Sources were selected based on their relevance to transport decarbonisation, data availability, and focus on Eurasian corridors. Priority was given to recent scholarly publications, international reports, and statistical datasets relevant to Eurasian logistics corridors. Policy documents were used to examine the regulatory context, while corporate and industry materials were used selectively to illustrate practical developments and were not treated as the primary basis for analytical conclusions. Media sources were used only where they provided relevant contextual information. Inclusion criteria included the availability of comparable data on transport systems, emissions, or infrastructure, while sources without clear methodological grounding were excluded from the core analysis.

The analysis focused on key themes such as infrastructure, digitalisation, and environmental performance, followed by a comparison of the Middle and Zangezur corridors through thematic grouping of data. The procedure included data selection, thematic coding, and comparative interpretation. The principal units of analysis were the Middle and Zangezur transport corridors and the institutional, technological, and infrastructure factors influencing their decarbonisation pathways.

The study draws on international reports and statistical sources (Organisation for Economic Co-operation and Development [OECD] 2023; International Transport Forum [ITF] 2021; World Bank 2023; United Nations Economic Commission for Europe [UNECE] 2021), complemented by industry and regional data on routing practices, infrastructure, and transit flows.

The legal and institutional context was examined through key frameworks, including the Paris Agreement (2015), Carbon Border Adjustment Mechanism (CBAM), and digital transit systems such as electronic Transports Internationaux

Routiers (eTIR) (UNECE 2021) and electronic Consignment Note (eCMR) (TransFollow 2026). This made it possible to identify regulatory factors influencing route choice and the shift towards lower-carbon transport.

The environmental dimension was assessed using both qualitative and selected quantitative indicators, including route length, modal structure, level of digitalisation, and reported emission effects. These indicators helped to compare corridor performance and trace patterns in the transition to lower-carbon transport. The comparison is based on differences in corridor characteristics and reported performance indicators across sources. Quantitative estimates are based on secondary sources and are treated as indicative ranges rather than exact measurements.

Results

Institutional foundations of green logistics and economic mechanisms of sustainability

Green logistics is shaped by the interaction of climate policy, trade regulation, and transport governance. In transregional transport, carbon footprint has become an important performance indicator alongside cost and speed. This shift is reflected in the development of green transport corridors and related policy initiatives.

These changes are reflected in the development of green transport corridors, as discussed in existing policy frameworks. The Clydebank Declaration, adopted at COP26, marked a coordinated effort to reduce emissions along key shipping routes (GOV.UK 2023). This points to the need for cooperation between governments, ports, and logistics operators, particularly in relation to fuel standards, infrastructure, and emissions reporting.

Decarbonisation is often framed through the "Avoid-Shift-Improve" approach, which focuses on reducing transport demand, shifting to less carbon-intensive modes, and improving technologies (Jarre et al. 2024). Its implementation depends on coordinated regulatory and infrastructure measures. At the same time, carbon transparency across supply chains is increasingly important, as emissions accounting affects competitiveness and access to regulated markets (Onyeaka et al. 2024).

Economic mechanisms play a central role in this transition. Carbon taxes, emissions trading systems, and differentiated tariffs create incentives for fleet modernisation and route optimisation (Peng et al. 2024), influencing both modal choice and corridor configuration. Emissions trading systems, in particular, encourage reductions in carbon intensity, while their implementation supports the digitalisation of logistics through monitoring and reporting procedures.

Overall, international agreements, national strategies, and carbon markets support the transition to lower-carbon transport systems (Humphreys and Dumitrescu

2021). They support emission reduction while improving the stability and predictability of logistics operations.

International initiatives for the formation of a sustainable green logistics architecture

International climate policy increasingly affects how logistics systems are organised and how transport is decarbonised. The Paris Agreement (2015) set the 1.5°C target and brought transport into national climate commitments. Later COP meetings continued in the same direction, with more attention to emission reduction and climate financing (United Nations (UN) 2023; 2024). Table 1 summarises key initiatives.

Table 1. International climate initiatives and their impact on transregional logistics

Initiative	Key focus	Logistics effect
Paris Agreement	Emission reduction targets	Integration into national transport policies
COP Conferences	Climate commitments	Support for green infrastructure and regulation
Clydebank Declaration	Green shipping corridors	Development of low-emission maritime routes
Belt and Road Initiative	Sustainable infrastructure	Electrification and standardisation
EU CBAM	Carbon pricing	Incentives to reduce carbon intensity

Source: own elaboration based on the UN (2023; 2024), Paris Agreement (2015), GOV.UK (2023), European External Action Service (2021)

Digital tools are presented in the literature as an important part of this transition. The eTIR system, introduced in 2021, allows paperless transit and real-time data exchange, which may reduce border delays and related emissions (UNECE 2021). Its wider implementation, however, depends on the interoperability of national digital systems and the harmonisation of customs procedures across participating countries. In some reported cases, time savings may reach 80%, while costs can fall by up to 38% (Caspian Policy Centre 2025).

Electronic consignment notes (eCMR) support the move towards unified digital platforms in cross-border transport (TransFollow 2026). Other tools, including artificial intelligence, monitoring systems, and route optimisation, are associated with lower emissions by reducing empty runs and unnecessary fuel use (Nicoletti and Appolloni 2024). Table 2 summarises key instruments.

Table 2. Digital and institutional initiatives in logistics and their environmental effect

Instrument	Function	Environmental effect
eTIR	Paperless transit	Less delay, lower emissions
eCMR	Digital documentation	Faster processing
Transport Management Systems (TMS) and Internet of Things (IoT)	Monitoring & routing	Lower fuel use
International Climate Initiative (IKI)	Policy support	Supports decarbonisation
Multilateral Development Bank (MDB) financing	Infrastructure funding	Enables low-carbon transport

Source: own elaboration based on UNECE (2021), Caspian Policy Centre (2025)

International initiatives also support emissions modelling and transport decarbonisation strategies (ITF 2021; OECD 2023).

Integration of corporate standards and digital solutions in green logistics

Global climate agreements and corporate commitments are shaping how logistics systems function. Cost and speed remain important, but emissions are now part of performance assessment. The shift towards low-carbon logistics also affects economic outcomes. More efficient and less carbon-intensive transport can improve market access and support infrastructure development, especially in regions that aim to expand their role in international trade (World Bank 2023). Sustainability is increasingly incorporated into logistics planning and performance assessment.

Transregional transport corridors – Infrastructure and carbon footprint reduction

Transregional transport corridors play a key role in international trade. They are associated with differences in freight movement and reported carbon intensity. The Middle and Zangezur corridors connect Central Asia, the Caucasus, and Europe and offer lower-emission alternatives to existing routes. The reported emission estimates presented in this section are derived from heterogeneous secondary sources and should be interpreted as indicative ranges rather than directly comparable measurements.

The Middle Corridor links China with Europe through Central Asia and the Caspian region, providing an alternative to longer maritime and road routes. Recent international assessments also identify the corridor as a strategic Eurasian route with the potential to substantially increase freight volumes and reduce transit time

through coordinated infrastructure investment and policy reforms (World Bank 2023; Valansi 2025; Zhou et al. 2023). Its Trans-Caspian format relies on a mix of rail and maritime transport. This combination tends to reduce emissions. Estimates from international sources suggest, under reported multimodal freight scenarios, CO_2 emissions may fall by 30-60% per tonne-kilometre (ITF 2021; International Road and Transport Union 2025).

The corridor is currently being upgraded, including the electrification of key railway lines and the expansion of port infrastructure to improve energy efficiency and capacity. According to available studies, reported emission reductions associated with railway electrification may range from 20% to 40%, depending on the energy mix and operational conditions (Bulková et al. 2025; World Bank 2023).

Digital tools are also part of these changes. Monitoring systems and route coordination are associated with lower idle time and reduced fuel use. In some reported cases, digital monitoring and route coordination have been associated with emission reductions of approximately 10-20% (UNECE 2021; Caspian Policy Centre 2025).

The Zangezur Corridor provides a shorter land route between Azerbaijan, Nakhchivan, and Turkey. Shorter distances, together with a greater use of rail, are associated with lower energy use and emissions. Reported estimates suggest emission reductions of 15-30% when shorter routes and greater rail use are combined, although these figures are derived from different analytical contexts (Ye 2025; Bulková et al. 2025). It also allows environmental standards to be introduced at an early stage of development.

Available evidence suggests that these corridors may support more flexible and lower-carbon supply chains. Table 3 summarises their main characteristics.

Table 3. Comprehensive characteristics of the Zangezur and Middle Corridors

Dimension	Middle Corridor	Zangezur Corridor
Structure	Multimodal (rail + sea)	Land-based (rail potential)
Route length	Longer, transregional	Shorter, regional
Key advantage	Modal shift reduces emissions	Distance reduction
Development stage	Ongoing modernisation	Early-stage development
Environmental tools	Emissions monitoring, digital systems	Integration of green standards
Emission potential	30-60% (est.)	15-30% (est.)
Economic role	Diversification of Eurasian routes	Strengthening regional connectivity

Source: own elaboration based on Bulková et al. (2025), Ye (2025), Watson Farley and Williams LLP (2022)

Overall, the Middle Corridor strengthens multimodal transport, while the Zangezur Corridor reduces distances and simplifies route structure. Both may

contribute to lowering emissions, according to available evidence in Eurasian transport networks.

Strategies for reducing the carbon footprint in international trade

Available evidence suggests that decarbonisation in international trade is shaped by a mix of state policies and business decisions. In Azerbaijan, this is reflected in the Strategic Roadmap, which prioritises electrification, digital tools, and integration into the eTIR system (Caspian Policy Centre 2025). A separate agreement with China focuses on multimodal transport within the Belt and Road framework, with an emphasis on energy efficiency (McKinsey Insights 2024). In practice, available evidence suggests that the use of eTIR reduces paperwork, shortens delays, and limits empty runs.

At the company level, changes are more gradual. European operators tend to focus on fleet upgrades, fuel choices, and monitoring systems. In maritime transport, the emphasis is usually on vessel modernisation and emissions reporting (Deutsche Bahn AG 2022). Some companies are also expanding low-emission routes and applying carbon accounting across supply chains (Kuehne + Nagel Group 2026), although this varies by region.

In Asia, similar trends are visible, but with a stronger focus on rail and multimodal solutions (Humphreys and Dumitrescu 2021). Within Belt and Road projects, coordination may help redistribute freight flows and avoid inefficiencies (McKinsey Insights 2024).

Rail transport is gaining attention, largely due to its lower emission intensity, and offers an alternative to road transport while allowing integration with low-carbon energy sources (Office of Rail and Road 2025). Its impact depends on how different transport modes are combined in practice (Briand et al. 2024).

Supply chain structure also matters. Fewer transhipments, better tracking, and route adjustments are associated with lower fuel use (Sarker and Kabir 2025). This can be seen, for example, in logistics centres such as the Absheron hub, where storage and handling are organised with energy efficiency in mind (Humphreys and Dumitrescu 2021). These measures are associated with gradual emission reductions and improved supply chain stability.

Discussion

International logistics is shaped by the climate agenda, shifting geo-economic conditions, and the digitalisation of transport systems. Multimodal transport, low-carbon technologies, and regulation are reshaping supply chains. The analysis

suggests that institutional measures, corporate decarbonisation strategies, and digital tools play an important role in reducing the carbon footprint of international trade. However, these changes do not operate in isolation. In practice, the environmental effect of logistics transformation depends on how these elements interact within specific corridor configurations, rather than on any single instrument taken separately.

Research increasingly links logistics efficiency with environmental outcomes. Cheng et al. (2024) and Hayyat et al. (2025) suggest that improvements in logistics systems support the adoption of low-carbon solutions and environmental technologies. This is consistent with the findings of the present study, where digitalisation, infrastructure upgrades, and institutional coordination contribute to the integration of environmental criteria into transport management. In this respect, the present study contributes a comparative analytical framework linking institutional coordination, digitalisation, and infrastructure development, suggesting that the same set of instruments may produce different outcomes depending on route structure, modal composition, and institutional coordination.

Economic instruments also matter. Mundaca et al. (2021) argue that carbon pricing affects route selection and encourages a shift to less carbon-intensive modes. This corresponds to the reorientation of freight flows towards rail and multimodal transport reported in the analysed cases.

Infrastructure and corridor development remain central. Previous studies and recent international assessments indicate that expanding the Middle Corridor improves reliability and may reduce delivery time and emissions, while infrastructure modernisation and institutional coordination remain critical for increasing corridor capacity (Arisoy and Gokasar 2025; World Bank 2023; OECD 2023). Port infrastructure also plays a key role in enabling green shipping corridors (Ismail et al. 2024). At the same time, the comparison of the Middle and Zangezur corridors suggests that emission reduction follows two distinct pathways: through modal optimisation in more complex, multimodal systems, and through distance reduction in more compact land-based routes. This distinction has practical implications for logistics planning. It suggests that decarbonisation strategies should be adapted to corridor characteristics, as measures that are effective in multimodal systems may not produce the same outcomes in shorter land-based transport networks. The present analysis suggests that these factors are most effective when implemented in combination rather than as isolated measures.

Digitalisation further affects environmental performance. Available evidence suggests that digital platforms improve efficiency and reduce resource use, while coordination between actors helps to limit empty runs and improve transport utilisation (Nicoletti and Appolloni 2024).

The transition to low-carbon logistics is closely linked to institutional and economic conditions. Coordination between policy, technology, and corporate strategies

appears central to this process, while state policy and reforms remain particularly important in the case of Azerbaijan (Wu et al. 2025; Suleymanov et al. 2025).

Thus, the shift towards sustainable logistics depends on the interaction of infrastructure, technology, and institutional coordination. In this context, the Middle and Zangezur corridors, together with digitalisation and emission management tools, can be seen as part of a broader move towards lower-carbon models of international transport. These findings should be treated with caution. The analysis relies on secondary data and reported estimates, which vary in methodology and scope. This limits direct comparability and points to the need for more standardised indicators of environmental performance in transregional transport.

Conclusions

In relation to the research objective, the analysis suggests that the carbon footprint of international trade depends not so much on infrastructure scale as on how different elements work together in practice. Institutional settings, technology, and operational decisions all play a role. Digital tools, coordination, and green corridors are increasingly used to reduce emissions, although the results vary across contexts.

The synthesis also points to the importance of the Middle and Zangezur corridors. Their development is linked to a gradual shift towards lower-emission transport and more efficient freight movement. Electrification, digital transit systems, and port upgrades support this process.

Institutional conditions also matter. When national policies are broadly aligned with frameworks such as the Paris Agreement, the Clydebank Declaration, or systems like eTIR, transport operations tend to become more predictable. The case of Azerbaijan illustrates how infrastructure development, combined with international cooperation, can support integration into emerging low-carbon transport networks.

For regional stakeholders, these findings suggest the importance of strengthening digital interoperability, supporting multimodal infrastructure, and improving the coordination of environmental standards across transport corridors. Greater alignment between policy frameworks and logistics operations may help bridge the gap between strategic decarbonisation goals and their practical implementation. Across the analysed corridors, digitalisation, electrification, and carbon transparency emerge as key enabling factors for lower-carbon logistics.

This study has several limitations, including differences in reporting systems, uneven data availability, and varying levels of digital readiness. Further research could focus on how digitalisation affects emissions in practice, as well as on developing comparable indicators for transregional corridors.

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