

Customs Efficiency and Logistics Performance in Azerbaijan: Implications for International Trade Development

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Abstract. *This article examines two key determinants of Azerbaijan's international trade performance — customs efficiency and logistics performance — analysing their current state, developmental trajectory, and future prospects. Strategically situated at the crossroads of Europe and Asia, Azerbaijan has made substantial investments in transport infrastructure over the past decade, defined the principal directions of its digital transformation agenda, and is progressively strengthening financial mechanisms to support a transition toward a green economy. Drawing on a structured narrative review of literature published largely between 2016 and 2026, the study discusses established evaluation frameworks such as Data Envelopment Analysis (DEA) and the Logistics Performance Index (LPI), fuzzy logic-based management models, hybrid fuzzy logic–genetic algorithm (FL–GA) optimisation architectures originally designed for IoT-enabled fog–cloud networks, the Baku–Tbilisi–Kars (BTK) railway project, e-logistics platforms, and the influence of geopolitical factors on trade. The synthesis indicates that the prevailing technological gap in customs and logistics operations represents a structural rather than transitional constraint, but the rapid pace of scientific and technological advancement implies a comparatively short window for catch-up. The article concludes that sustainable trade growth requires the integrated modernisation of the customs–logistics system alongside coordinated green-finance and infrastructure policy.*

Keywords: *customs efficiency, logistics performance, international trade, fuzzy logic, hybrid optimization, digital transformation, green economy, Azerbaijan*

Introduction

In an era of deepening economic globalisation and increasingly complex supply-chain architectures, the speed and transparency of customs procedures have ceased to be a purely technical administrative matter. They constitute a strategic variable that shapes a country's competitive positioning in international markets. Azerbaijan represents a particularly instructive case in this regard: the country occupies a geographically privileged location along the East–West and North–South corridors, possesses a transit tradition rooted in the historical Silk Road, and has pursued a consistent agenda of foreign-trade liberalisation since independence. And yet the full realisation of this potential remains elusive. Full alignment of customs services with contemporary international standards, reduction of sectoral disparities in logistics infrastructure, and the integration of digital technologies into operational processes remain open priorities (Samadova et al., 2025).

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Compounding these challenges, geopolitical tensions in the region complicate the planning of transit routes and exert a direct bearing on the investment climate. A further dimension that recent scholarship has brought into focus concerns technological lag. In the current developmental phase, the gap between available digital solutions and their actual deployment in customs and logistics operations is not merely persistent — it is expected to widen in the near term as the frontier of technology advances more rapidly than institutional capacity to absorb it. Paradoxically, however, the very pace of scientific and technological progress also implies that if current reform trajectories are sustained, Azerbaijan may reach meaningful levels of adoption considerably sooner than linear extrapolation would suggest.

This article advances the view that customs modernisation and logistics digitalisation are not sequential but parallel processes — each reinforcing the other — and that Azerbaijan is, in fact, integrating into this dual transformation at a pace that deserves more systematic attention in the literature. Against this backdrop, the article draws on the existing research base to analyse the interplay between customs efficiency and logistics performance in shaping trade outcomes, while incorporating the broader sustainability dimensions of green-economy financing (Abdulhasanova, 2025) and the relationship between renewable energy consumption and economic growth (Ahmadova et al., 2024). A particular emphasis is placed on hybrid optimisation architectures — most notably the fuzzy logic–genetic algorithm (FL–GA) framework recently formalised by Venkata Srinivas et al. (2025) — as a methodological bridge between distributed-computing research and the operational realities of customs administration.

The objectives of this study are: (i) to map the contemporary methodological frameworks for assessing customs and logistics performance with reference to the Azerbaijani context; (ii) to evaluate the empirical evidence on the trade-development effects of infrastructure investment and digital transformation; (iii) to articulate the linkages between green-economy financing and the customs–logistics reform agenda; and (iv) to identify research gaps that warrant prioritised empirical investigation.

Methods

This article adopts a structured narrative literature review approach to synthesise the contemporary evidence base on customs efficiency, logistics performance, and their joint role in shaping Azerbaijan's international trade outcomes. Sources were identified through systematic searches of Scopus, Web of Science, Google Scholar, and IEEE Xplore, complemented by targeted retrieval of policy documents and Azerbaijani-context studies indexed by national academic publishers. The search strategy combined keyword sets covering "customs efficiency," "logistics performance", "fuzzy logic", "genetic algorithm", "blockchain", "green economy", "Azerbaijan" and "Middle Corridor" in English, Russian, and Azerbaijani.

Inclusion was restricted to peer-reviewed publications, conference proceedings indexed by reputable databases, and government-affiliated reports. Priority was assigned to studies published between 2016 and 2026, although seminal earlier contributions (e.g., Bleikher et al., 2016) were retained where directly relevant. The selected studies were thematically organised around four analytical axes: (i) frameworks for measuring customs efficiency (DEA, LPI, KPI systems, fuzzy logic, and hybrid optimisation models); (ii) logistics infrastructure and trade expansion (econometric studies including ARDL bounds testing); (iii) green-economy financing and sustainable logistics; and (iv) geopolitical risk and route selection.

The analytical framework rests on a methodological premise that customs and logistics performance cannot be assessed in isolation: established quantitative tools such as DEA and LPI capture different but complementary dimensions of efficiency, while emerging hybrid approaches — particularly the

fuzzy logic–genetic algorithm (FL–GA) framework formalised by Venkata Srinivas et al. (2025) for IoT-enabled fog–cloud networks — offer a methodological bridge between operational research and trade policy. Findings were synthesised using a thematic-comparative method, in which patterns identified across the literature are interpreted in relation to Azerbaijan's institutional, infrastructural, and geopolitical context. Where empirical estimates are reported (e.g., Mahmudov, 2023, on infrastructure-investment elasticities), the original quantitative findings are preserved; where conceptual frameworks are reviewed (e.g., circular intuitionistic fuzzy models), their methodological logic is examined for transferability to customs operations.

Results

Frameworks for Measuring Customs Efficiency

International practice draws on several well-established methodologies for evaluating customs performance. Data Envelopment Analysis (DEA) is the most widely applied quantitative tool, enabling the systematic assessment of input–output relationships in customs operations (Acar&ÖzerTorgalöz, 2022). The World Bank's Logistics Performance Index (LPI) provides a standardised comparative framework through sub-indicators covering timeliness of customs clearance, infrastructure quality, the competitiveness of logistics service providers, and shipment-tracking capabilities (Önselekici et al., 2016; Sharawi et al., 2025).

In Azerbaijan, increasing attention has been directed toward Key Performance Indicators (KPIs) for customs personnel, which link national strategic objectives to the mechanisms of the World Customs Organization (WCO). This shift renders the assessment process more transparent and accountability structures more robust (Cherkunov, 2025). The universal indicator system developed by Bobrova and Garipov (2018), which incorporates both the perspective of customs authorities and that of foreign economic activity participants, represents a methodologically significant contribution, offering a dual-lens approach to performance evaluation.

A persistent structural challenge, however, is the proliferation of metrics across different methodological traditions, which generates indicator duplication and weakens comparability. This has prompted growing calls for harmonised, integrated systems capable of providing multidimensional assessments that reflect both operational efficiency and service-quality dimensions.

Fuzzy-logic models have emerged as among the most promising instruments for optimising decision-making processes in conditions of operational uncertainty — precisely the conditions that characterise complex logistics and customs environments. Aghayev (2025), working in the Azerbaijani context, developed a fuzzy logic-based model for managing air-passenger transport processes, demonstrating the practical effectiveness of this approach in real-world logistics applications and thereby establishing a methodological foundation for its analogous deployment in customs clearance. Azerbaijani contributions to the dynamic assessment of economic uncertainty through fuzzy approaches (Imanov et al., 2025) reinforce this picture, while supporting evidence from fuzzy modelling in tax administration further confirms the potential (Musayev&Gazanfarli, 2022).

Hybrid Optimisation: From IoT-Enabled Fog–Cloud Networks to Customs Operations

Building on the fuzzy-logic literature, recent work has demonstrated that the most substantial performance gains arise not from fuzzy reasoning in isolation but from its integration with evolutionary search heuristics. Venkata Srinivas et al. (2025) propose a hybrid fuzzy logic–genetic algorithm (FL–GA) framework for energy-efficient task scheduling in IoT-enabled fog–cloud networks, in which the fuzzy component absorbs the imprecision intrinsic to multi-source operational data, while the genetic-algorithm component performs combinatorial search over the decision space. The resulting architecture systematically reduces energy consumption and processing latency relative to conventional schedulers.

The conceptual transposition of this framework to customs administration is direct and instructive. A modern customs environment generates exactly the data profile that FL–GA architectures are designed to handle: large volumes of heterogeneous declarations, partially observed risk indicators, fluctuating arrival rates of goods, and a substantial set of operational constraints (lane capacity, inspector availability, dwell-time limits). The fuzzy layer can encode the inherent vagueness of risk-profiling inputs — "high-value cargo," "frequent declarant," "sensitive origin" — without forcing premature crisp classification, while the genetic-algorithm layer can search the joint scheduling space of inspections, document verifications, and lane assignments to minimise weighted total clearance time (Venkata Srinivas et al., 2025).

A second, frequently overlooked feature of the FL–GA architecture is the explicit treatment of energy consumption as an objective. Customs IT infrastructure — single-window servers, X-ray and CT scanners, biometric systems, and the fog/edge nodes increasingly deployed at border crossings — represents a non-trivial energy load. Importing the energy-aware scheduling logic of Venkata Srinivas et al. (2025) into customs IT operations therefore connects directly with Azerbaijan's broader green-economy commitments (Abdulhasanova, 2025), turning what would otherwise be a purely operational efficiency question into one with measurable environmental implications.

Complementary evidence supports this direction. On the broader digital-transformation front, Mahmudova et al. (2025) demonstrate that the integration of artificial intelligence, Big Data, and blockchain technologies into transport systems functions as a genuine catalyst for economic modernisation. Babayev and Virkovski (2026) have formulated specific approaches to the digitalisation of national segments of international transport corridors crossing Azerbaijani territory. The persistent lag of the legal and regulatory framework behind the pace of technological advancement, however, remains a significant structural impediment (Muradov, 2022). Although Azerbaijan is not a member of the Eurasian Economic Union (EAEU), the methodological apparatus developed within that organisation for customs-administration modernisation — multi-level indicator systems, blockchain-enabled documentation, multi-factor traceability platforms — constitutes a relevant reference framework (Davydov, 2021; Vovchenko et al., 2022; Bleikher et al., 2016).

Logistics Performance and Trade Expansion

The empirical literature provides a robust evidentiary base for the direct transmission of logistics-infrastructure investment into improved trade outcomes. Samadova et al. (2025), in a cross-country comparative analysis, found that a one-percentage-point increase in road and rail investment yields a measurable expansion of transport capacity within one to two years. Their study also quantifies the positive effects of strategic infrastructure projects — including the expansion of the Baku International Sea Trade Port — on trade turnover and transit-revenue generation.

At the macroeconomic level, Mahmudov (2023), employing the ARDL bounds-testing approach, establishes that transport-infrastructure investment exerts a statistically significant positive effect on real GDP, with the implied elasticity suggesting approximately 0.47 percentage points of additional real growth per unit of sectoral investment. This figure underlines the multiplier logic behind infrastructure spending: each unit of capital committed to transport infrastructure generates returns that extend well beyond the sector itself.

Niftiyev (2024) draws attention to a critical structural imbalance: while aviation, maritime, and road transport demonstrate positive performance trends, the railway sector continues to lag substantially behind and requires comprehensive reform. This sectoral asymmetry constitutes what may be termed the weakest link in Azerbaijan's otherwise strengthening logistics chain.

The commissioning of the Baku–Tbilisi–Kars (BTK) railway in 2017 fundamentally reconfigured Azerbaijan's positioning in regional trade networks. The project transformed Azerbaijan into a principal node for freight transit along the Middle Corridor while deepening connectivity with European, South Caucasus, and Central Asian markets (Orujov, 2019). Comparative analyses indicate that Azerbaijan has surpassed Iran in Caspian trade potential — a finding that attests to the long-term economic impact of sustained commitment to multimodal infrastructure (Khan et al., 2023).

Imamguluyev and Suleymanov (2022) formalised the strategic objectives of Azerbaijan's logistics system using a fuzzy-logic model, demonstrating that the full realisation of the BTK's capacity requires not only further technical infrastructure development but also the concurrent modernisation of management systems and operational decision-making frameworks. Notably, the same hybrid optimisation logic that underpins the FL–GA framework of Venkata Srinivas et al. (2025) — fuzzy reasoning over imprecise inputs combined with evolutionary search across operational constraints — is well-suited to the kind of multi-objective scheduling that BTK corridor management increasingly demands, where transit times, energy use, and capacity-allocation decisions must be reconciled in real time.

The rapid expansion of e-commerce has brought into sharp relief the incomplete segment of the logistics chain: last-mile delivery. Ahmadov (2026) identifies urban traffic congestion, resource-planning deficiencies, and the instability of service-quality standards as the primary operational bottlenecks in Azerbaijan's e-commerce logistics landscape. Gasimov et al. (2024) provide quantitative evidence for the positive and measurable impact of information and communication technologies on Azerbaijan's transport sector. The integration of blockchain technology into national e-logistics platforms opens significant prospects in two complementary directions: enhancing the transparency of customs documentation and improving the security of cross-border data exchange (Babayev & Virkovski, 2026). The COVID-19 pandemic, for all its disruptions, accelerated digital transformation and demonstrably strengthened the resilience of SMEs in the sector (Abilova & Aliyeva, 2022).

Green Economy, Sustainable Logistics, and Finance

A significant development in recent scholarship is the integration of customs and logistics questions into a broader sustainability framework. Ahmadova et al. (2024) examine the relationship between renewable energy consumption and economic growth through a comparative empirical study of Iceland and Azerbaijan, finding that the energy–economy nexus in Azerbaijan is characterised by complex, multi-directional dynamics that bear directly on the country's foreign-trade balance and overall export competitiveness. From a logistics standpoint, the implication is clear: energy and transport infrastructure cannot be planned in isolation if long-term sustainability is the objective.

Abdulhasanova (2025) addresses the financial dimension of this challenge directly. Her research identifies the magnitude of the financing gap that Azerbaijan faces in transitioning to a green economy and proposes concrete capital-mobilisation mechanisms — including targeted green-bond instruments and public–private co-financing structures — to address it. The relevance to logistics modernisation is immediate: the electrification of transport fleets, the retrofitting of warehousing facilities to energy-efficient standards, and the deployment of digital tracking infrastructure all require substantial up-front capital that current public budgets cannot absorb unaided.

The energy dimension extends naturally to the digital backbone of customs and logistics itself. As Venkata Srinivas et al. (2025) demonstrate in the IoT-enabled fog–cloud context, a substantial share of the energy consumed by distributed digital infrastructure is recoverable through algorithmic optimisation rather than hardware replacement. Translated to Azerbaijan's customs IT environment — where edge sensors, scanning systems, and single-window architectures collectively constitute a

non-negligible energy load — this finding suggests that green-logistics policy should incorporate the digital infrastructure on which modern trade facilitation depends.

At the sectoral level, Mehdiyeva et al. (2020) identify logistics infrastructure as the primary enabling factor for green supply-chain management in Azerbaijan's agricultural sector. Container shipping, as Nuraliyeva et al. (2025) demonstrate, offers both cost advantages and measurable reductions in environmental footprint — suggesting that customs-tariff policy can be designed to actively incentivise greener transport choices rather than simply accommodate them.

Geopolitical Factors and Regional Specificities

The formation of logistics strategy in Azerbaijan is shaped no less — and sometimes more — by geopolitical considerations than by purely economic calculus. Regional conflicts affect transit-route selection, investment decisions, and the durability of international partnerships, rendering robust risk management an integral component of strategic planning rather than an optional supplement to it (Depren et al., 2024; Yalçın et al., 2025).

Research drawing on data from post-Soviet states demonstrates that institutional quality — the transparency of public administration, the strength of the rule of law — exerts a statistically significant positive effect on economic growth (Gasimov et al., 2023). This finding carries a dual implication for Azerbaijan: reducing corruption risk within customs administration simultaneously lowers effective trade costs and shapes the perceptions of foreign investors.

The application of circular intuitionistic fuzzy models to the selection of Asia–Europe logistics-route alternatives (Imanov et al., 2024) offers a methodologically sophisticated response to the challenge of route choice under geopolitical uncertainty. The methodological neighbourhood is broader still: the FL–GA architecture proposed by Venkata Srinivas et al. (2025), although developed for distributed-computing applications, embodies the same operational logic that route-selection problems demand — uncertainty-tolerant input representation combined with global combinatorial search. This convergence suggests that the methodological migration of techniques between domains (computer networks ↔ trade-corridor planning) is no longer speculative but actively underway, and Azerbaijani decision-support systems can plausibly draw on either lineage.

Discussion

The synthesis of the literature reviewed in this article points to several interlocking findings that, taken together, define the contemporary research frontier on Azerbaijan's customs–logistics performance. First, Azerbaijan's geographical position creates a genuine structural advantage in the organisation of Eurasian transit trade; however, fully realising this advantage requires the concurrent application of advanced digital solutions, harmonised customs procedures, and sustainable financing mechanisms. The geographical asset, in other words, must be matched by an institutional asset.

Second, fuzzy logic, hybrid optimisation algorithms — exemplified by the FL–GA framework of Venkata Srinivas et al. (2025) — and blockchain technology represent not future possibilities but increasingly available instruments, and their integration into Azerbaijan's customs and logistics architecture is both technically feasible and economically warranted. The regulatory framework's lag behind technological capacity, identified by Muradov (2022) and corroborated implicitly across the digitalisation literature, is a structural constraint that demands proactive rather than reactive policy responses. The methodological bridge between distributed-computing research and trade-policy implementation, articulated in Section 3.2, is one of the more underexploited resources in the current literature.

Third, the technological gap that currently characterises Azerbaijan's customs–logistics system is not static. In the present phase of rapid scientific and technological advancement, this gap is expected to deepen unless accelerated adoption measures are implemented. Conversely, the very pace of that advancement also implies that the window for catch-up may be shorter than historical analogies suggest: if institutional capacity is built now, Azerbaijan could reach meaningful levels of digital integration faster than linear forecasts indicate. Fourth, digitalisation and logistics-infrastructure development are parallel, mutually reinforcing processes, not sequential stages of a linear reform path. The evidence reviewed suggests that Azerbaijan is, in fact, engaging with both simultaneously and integrating into the broader Eurasian digital-logistics transformation at a pace that merits recognition.

Fifth, the green-economy transition — its financing gaps (Abdulhasanova, 2025), its energy-growth dynamics (Ahmadova et al., 2024), and the energy efficiency of digital customs infrastructure itself (Venkata Srinivas et al., 2025) — must be embedded within, rather than appended to, the customs–logistics reform agenda. Sustainable logistics is not a separate policy domain; it is the destination toward which the reform trajectory should be oriented. Sixth, the railway sector remains the most significant structural weakness in Azerbaijan's logistics profile (Niftiyev, 2024); targeted investment, international-standards alignment, and innovative management approaches are prerequisites for correcting this imbalance.

Research Gaps and Future Directions

Several research gaps emerge from this synthesis. First, there is a notable absence of direct empirical studies on the impact of fuzzy logic and AI on customs-clearance times in the Azerbaijani context; available evidence is methodological or analogical rather than dataset-driven. Second, integrated models combining digital transformation with multimodal-logistics optimisation under geopolitical-risk scenarios remain underdeveloped. Third, sector-specific green supply-chain research — beyond the agricultural sector studied by Mehdiyeva et al. (2020) — is sparse. A particularly promising avenue is the empirical adaptation of FL–GA hybrid optimisation (Srinivas et al., 2025) to Azerbaijani customs-clearance data, which would simultaneously address the algorithmic and the energy-efficiency dimensions of the modernisation agenda. Addressing these gaps through empirical, interdisciplinary inquiry is the logical next step for the research community.

Conclusion

This article has examined the role of customs efficiency and logistics performance as drivers of international trade development in Azerbaijan, drawing on a wide body of empirical and methodological literature. The principal conclusion is that sustainable trade growth requires the integrated modernisation of the customs–logistics system alongside coordinated green-finance and infrastructure policy. Azerbaijan's geographical advantage, its existing investment trajectory in transport infrastructure (notably the BTK railway and the expansion of the Baku International Sea Trade Port), and its growing engagement with hybrid optimisation methodologies position it to convert a structural endowment into a sustained competitive position. The scale of this transformation, however, depends on whether the country's regulatory and financial architecture can keep pace with the technological frontier — a challenge that is at once formidable and, given the present pace of advancement, surmountable on a shorter horizon than conventional analogies would imply.

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