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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,""frequentdeclarant,""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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Economic and Ecological Analysis of the Relationship Between PM2.5 and PM10 Levels and Industrial and Transport Factors in the Cities of Sumgayit and Almaty

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Abstract. *Air pollution caused by fine and coarse particulate matter is a major environmental and public health issue in rapidly growing cities. This study offers an economic and ecological analysis of PM2.5 and PM10-related air pollution in Sumgayit, Azerbaijan, and Almaty, Kazakhstan. The research combines air quality data with photographic field observations to evaluate the link between particulate matter levels and key urban pollution factors. These factors include industrial activity, traffic congestion, construction processes, fog, smog, and the spatial characteristics of the urban environment. For Almaty, daily PM2.5 and PM10 concentration data from 2020 to 2025 came from AQICN/AirKaz monitoring data. In Sumgayit, PM2.5 data were sourced from the National Hydrometeorological Service under the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. PM10 values were estimated using a PM2.5/PM10 ratio method. Furthermore, photographic field observation data from both cities served as visual and contextual evidence to understand the potential contributions of transport, industrial activities, construction, and weather factors to particulate matter pollution. The study demonstrates that combining measured air quality data, estimated indicators, and field-based visual documentation can create a practical framework for comparing urban air pollution. The findings aim to aid environmental monitoring, urban planning, and discussions about green economy policies in both cities.*

Keywords: *Air pollution, particulate matter, Sumgayit, Almaty, industrial emissions, environmental monitoring*

Introduction

Air pollution is one of the most serious challenges facing urban health, economic productivity, and city development. Among various air pollutants, particulate matter is particularly significant due to its direct impact on respiratory and cardiovascular health. It is closely linked to transportation, industrial activity, construction, fuel burning, and urban weather patterns. PM2.5 refers to fine particles with a diameter of 2.5 micrometers or smaller, while PM10 includes inhalable particles with a diameter of 10 micrometers or smaller. Because of their smaller size, PM2.5 particles can penetrate deeper into the respiratory system, while PM10 is often related to road dust, construction, soil resuspension, and other larger particle sources (WHO, 2021).

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In rapidly growing industrial cities, PM2.5 and PM10 levels are influenced not only by direct emissions but also by the city's layout, weather conditions, traffic volume, industrial areas, and the presence of green spaces. Emissions from transport, brake and tire wear, road dust, industrial combustion, construction activity and stagnant atmospheric conditions are commonly reported as contributors to particulate matter pollution in urban areas (WHO, 2021; OECD, 2020). Road dust resuspension is especially relevant for PM10 because it depends on road surface conditions, traffic intensity, vehicle fleet characteristics and meteorological conditions (CasottiRienda& Alves, 2021).

Sumgayit and Almaty serve as two relevant urban examples for comparing particulate matter pollution. Sumgayit, one of Azerbaijan's main industrial cities, faces air quality challenges due to industrial activity, urban transport, construction, and the broader impact of its industrial history. In contrast, Almaty, one of Kazakhstan's largest cities, is often discussed in relation to traffic congestion, emissions from heating, nearby industrial areas, and poor atmospheric dispersion conditions. Its basin-like geography and episodes of temperature inversion may lead to the buildup of pollutants in the lower atmosphere, especially during cold weather (Almaty Air Initiative, 2024; WHO, 2021).

From an economic and ecological standpoint, particulate matter pollution is not just an environmental issue; it is also a development concern. High levels of PM2.5 and PM10 can raise health risks, lower worker productivity, generate extra healthcare costs, and diminish urban life quality. Air pollution also creates measurable economic costs through disease burden, premature mortality, welfare losses and additional pressure on public health systems (WHO Regional Office for Europe & OECD, 2015). The presence of industrial, transportation, and construction sources highlights the need for cleaner production methods, sustainable transport, dust management, environmental monitoring, and better urban planning. In this context, PM2.5 and PM10 levels are key indicators for assessing urban development sustainability. This study aims to examine the link between PM2.5 and PM10 levels and factors related to industry, transport, construction, and the urban environment in Sumgayit, Azerbaijan, and Almaty, Kazakhstan. The research relies on four supporting datasets: photographic observations from Almaty, photographic observations from Sumgayit, daily PM2.5 and PM10 concentration data for Almaty for 2020-2025, and PM2.5 with estimated PM10 data for Sumgayit from the National Hydrometeorological Service of Azerbaijan. The photographic data serve as visual and contextual evidence, while the numerical data enable trend analysis, annual and monthly comparisons, and interpretations of particulate matter patterns (Arifzade, 2026a; Arifzade, 2026b; Mammadov, 2026; Abbasova&Məmmədov, 2026).

The main contribution of this study is its combined methodological approach. Rather than relying solely on numerical air quality data, the paper connects PM2.5 and PM10 information with visual field observations related to traffic congestion, construction, industrial environments, fog, smog, and urban characteristics. This allows for interpreting particulate matter pollution not just as a number but as a visible issue linked to urban environments. Such an approach may be beneficial for environmental monitoring, urban policies focused on a green economy, and comparative studies of air pollution in post-Soviet and industrial urban areas.

Materials and methods

This study uses a mixed-data approach to compare PM2.5 and PM10-related urban air pollution factors in Sumgayit, Azerbaijan, and Almaty, Kazakhstan. The method combines numerical air quality datasets with photographic field observations. The numerical datasets help analyze particulate matter levels. The photographs support the interpretation of possible pollution sources, such as industrial activity, trafficcongestion, construction processes, fog or smog conditions, and visible urban environmental factors.

The study focuses on two urban areas: Sumgayit in Azerbaijan and Almaty in Kazakhstan. Sumgayit, an industrial city near the Caspian Sea, has a history of industrial production, urban expansion, and environmental pressure from transport. Almaty is a large urban center in Kazakhstan, located near the foothills of the Trans-Ili Alatau mountains. Here, air quality may be affected by traffic density, emissions from heating, industrial surroundings, topography, and weather conditions.

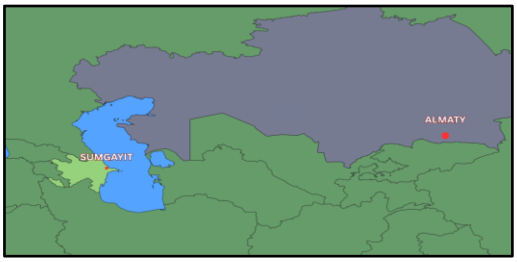

Figure 1

Location and general urban context of Sumgayit and Almaty

This study used four datasets. The first dataset includes photographic field observations related to PM2.5 and PM10 urban pollution factors in Almaty. It contains visual materials on fog, smog, construction activity, industrial surroundings, and traffic congestion (Arifzade, 2026a). The second dataset includes photographic field observations for Sumgayit, covering similar categories such as fog, smog, construction activity, industrial surroundings, and traffic congestion (Mammadov, 2026).

The third dataset contains daily PM2.5 and PM10 concentration data for Almaty from 2020 to 2025. These data are based on AQICN/AirKaz monitoring records and include daily minimum, maximum, median, quartiles, standard deviation, and observation count values (Arifzade, 2026b). The fourth dataset contains PM2.5 indicators for Sumgayit based on the National Hydrometeorological Service under the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. Since direct PM10 measurements were not available in this dataset, PM10 values were estimated using a PM2.5/PM10 ratio-based approach (Abbasova&Məmmədov, 2026).

Table 1

Main datasets used in the study

No.	Dataset	City	Data type	Period	Main purpose
1	*Photographic field observation dataset for Almaty*	*Almaty*	*Visual/field observation*	*2025–2026*	*Identification of visible pollution-related urban factors*
2	*Photographic field observation dataset for Sumgayit*	*Sumgayit*	*Visual/field observation*	*2019–2026*	*Identification of visible pollution-related urban factors*
3	*Daily PM2.5 and PM10 dataset for Almaty*	*Almaty*	*Numerical air quality data*	*2020–2025*	*Trend, annual, and monthly analysis*
4	*PM2.5 and estimated PM10 dataset for Sumgayit*	*Sumgayit*	*Numerical and estimated data*	*Based on available official data*	*Comparative interpretation of PM2.5 and estimated PM10*

The main air quality indicators used in this study are PM2.5 and PM10. PM2.5 refers to fine particulate matter with a diameter of 2.5 micrometers or smaller. PM10 refers to inhalable particulate matter with a diameter of 10 micrometers or smaller. PM2.5 is usually linked to combustion processes, traffic emissions, industrial fuel use, and the formation of secondary aerosols. PM10 can include both fine and coarse particles generated by road dust, construction activity, soil resuspension, industrial dust, and mechanical processes.

For Almaty, the daily median values of PM2.5 and PM10 were chosen as the main indicators for analysis. The median was preferred because it is less affected by extreme values than the maximum value. It offers a more stable view of daily particulate matter levels. Annual and monthly summaries helped to identify trends over time.

In Sumgayit, the available PM2.5 values served as the main official indicator. PM10 values were not regarded as directly measured data. Instead, they were estimated using the PM2.5/PM10 ratio method. This method assumes that PM2.5 makes up about 65 to 70 percent of PM10 under urban air pollution conditions. The estimated PM10 values were calculated using the following formulas:

$$PM10_{estimate}\ 1 = PM2.5 / 0.70$$
$$PM10_{estimate}\ 2 = PM2.5 / 0.65$$

This means that PM10 is presented as an estimated range rather than a single direct measurement. Therefore, the Sumgayit PM10 values should be interpreted only as approximate indicators for comparative research purposes.

Table 2
PM10 estimation approach used for Sumgayit

Indicator	**Formula**	**Interpretation**
Lower PM10 estimate	*PM2.5 / 0.70*	*Assumes PM2.5 forms 70% of PM10*
Upper PM10 estimate	*PM2.5 / 0.65*	*Assumes PM2.5 forms 65% of PM10*
Final PM10 value	*Estimated interval*	*Not a direct instrumental measurement*

Photographic field observation supported the documentation of visible sources and environmental conditions related to particulate matter pollution. The photographs fell into four main categories: fog or smog, construction activity, industrial surroundings, and traffic congestion. Each photograph included metadata such as category, date, location or coordinates, source, and a brief explanation of its relevance to PM2.5 and PM10 pollution. The PM2.5/PM10 ratio approach is used in air pollution studies to understand the relationship between fine and coarse particulate matter. Previous urban studies have reported PM2.5/PM10 ratios near this range under certain local conditions (Drăgoi et al,2025).

The photographic materials did not serve as direct measurements of pollution concentration. Instead, they provided context to understand the urban and environmental factors behind PM2.5 and PM10 patterns. For instance, traffic congestion was seen as a possible source of PM2.5 through exhaust emissions and of PM10 through dust resuspension, brake wear, and tire wear. Recent studies also show that non-exhaust traffic emissions, including brake and tyre wear particles, are important components of traffic-related particulate matter in urban environments (Beddows et al., 2023). Construction activity was mainly linked to PM10 due to dust generation and exposed soil surfaces. Construction dust has been widely discussed as an important source of particulate exposure, particularly where demolition, excavation, material storage and exposed surfaces are not effectively controlled (Wang et al., 2023). Industrial surroundings were viewed as potential sources of both fine and coarse particulate matter, depending on fuel type, production process, and emission control conditions.

Figure 2
Examples of photographic field observations from Almaty.
a) fog conditions; b) industrial surroundings; c) construction activity; d) traffic congestion

Figure 3
Examples of photographic field observations from Sumgayit.
a) fog conditions; b) industrial surroundings; c) construction activity; d) traffic congestion

The Almaty PM2.5 and PM10 datasets were processed using daily median values. The date variable was broken down into year and month components to calculate annual and monthly patterns. Annual summaries compared changes over time, while monthly summaries helped identify seasonal differences.

For Sumgayit, the available PM2.5 values were organized in a table, and estimated PM10 intervals were calculated using the 0.65 to 0.70 ratio method. These values were then analyzed alongside photographic field observations to connect particulate matter indicators to potential industrial, transport, construction, and urban environmental factors.

The analysis includes three main stages:

1. Organizing numerical and photographic datasets
2. Calculating annual and monthly PM2.5 and PM10 indicators
3. Interpreting air pollution patterns in relation to industrial, transport, construction, and urban environmental factors

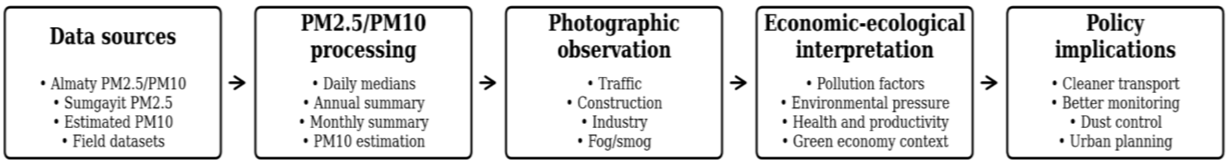

Figure 4
Methodological framework of the study

Results and discussion

The Almaty dataset offers daily PM2.5 and PM10 concentration data from 2020 to 2025. For the analysis, daily median values served as the main indicator because the median is less influenced by short-term extremes than the daily maximum. The annual summary reveals that both PM2.5 and PM10 levels changed significantly during the study period.

Table 3
Annual PM2.5 and PM10 indicators in Almaty based on daily median values, 2020–2025

Year	Available days	Average daily median PM2.5, µg/m³	Average daily median PM10, µg/m³	Median of daily PM10 medians, µg/m³
2020	*232*	*36.7*	*58.51*	*18.27*
2021	*326*	*44.67*	*72.24*	*28.73*
2022	*280*	*38.09*	*60.3*	*22.13*
2023	*285*	*41.02*	*64.5*	*26.4*
2024	*143*	*101.37*	*148.1*	*63.5*
2025	*359*	*43.76*	*54.99*	*24.92*

The results show that particulate matter levels in Almaty remained significant throughout the study period. The annual average daily median values for PM2.5 ranged from 36.70 µg/m³ in 2020 to 44.67 µg/m³ in 2021. For PM10, the range was from 58.51 µg/m³ in 2020 to 72.24 µg/m³ in 2021. In 2022 and 2023, the values stayed within a similar range. This indicates that particulate matter pollution was not just a one-year issue but a persistent problem for urban air quality. In 2024, annual averages for both PM2.5 and PM10 are much higher. However, this year also shows extremely high individual values and fewer available days compared to previous years. Therefore, the 2024 data should be interpreted with caution. It might indicate real pollution spikes, issues with the sensors, temporary extreme events, or problems with data quality. As such, the 2024 value can help identify a potential abnormal pollution period, but it should not be viewed as a straightforward long-term trend without further validation.

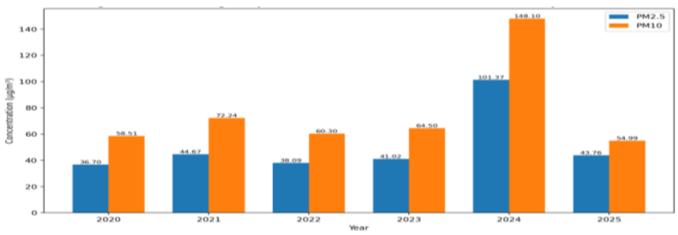

Figure 5
Annual average daily median PM2.5 and PM10 concentrations in Almaty, 2020–2025.
Source: Prepared by the authors based on Arifzade (2026b)

Monthly summaries show that PM2.5 and PM10 levels in Almaty were usually higher in the cold months and lower in the warmer ones. This pattern may be connected to emissions from heating, less atmospheric mixing, stagnant air, and temperature inversions. The winter months, particularly December, January, and February, had more buildup of particulate matter than the spring and summer months.

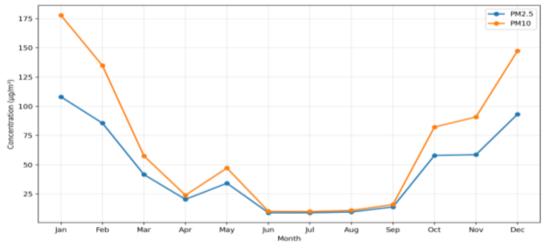

Figure 6

Monthly variation of PM2.5 and PM10 concentrations in Almaty, 2020–2025

For Sumgayit, official PM2.5 data came from the National Hydrometeorological Service under the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. Since direct PM10 values were not in the same dataset, we estimated PM10 using the PM2.5/PM10 ratio approach. These values should be seen as approximate indicators, not as direct PM10 measurements.

Table 4

PM2.5 and estimated PM10 values for Sumgayit

Year	City	Official PM2.5, µg/m³	Estimated PM10 minimum, µg/m³	Estimated PM10 maximum, µg/m³
2021	*Sumgayit*	*22*	*31.4*	*33.8*
2022	*Sumgayit*	*21*	*30*	*32.3*
2023	*Sumgayit*	*23*	*32.9*	*35.4*

The results show that PM2.5 values in Sumgayit remained fairly stable from 2021 to 2023. Estimated PM10 values also fluctuated within a small range. This indicates that particulate matter pollution in Sumgayit should be viewed alongside industrial activity, transport traffic, construction work, and local urban dust sources.

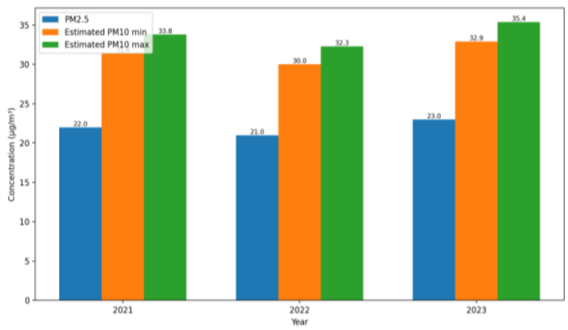

Figure 7

PM2.5 and estimated PM10 values in Sumgayit, 2021–2023

The photographic field observation datasets help interpret the numerical results by showing visible urban factors related to particulate matter pollution in Almaty and Sumgayit. The examples in Figures 2 and 3 include fog, smog, industrial areas, construction activity, and traffic jams. These factors can increase PM2.5 through combustion, transport, and industrial emissions, and PM10 through road dust, construction dust, tire and brake wear, and resuspended particles.

In Almaty, higher levels of particulate matter, especially in cold months, may relate to traffic density, heating-season emissions, industrial areas, and poor atmospheric conditions. In Sumgayit, stable PM2.5 values and estimated PM10 intervals should connect with the city's industrial profile, construction activity, transport flow, and local dust sources. While photographic materials do not directly measure air pollution, they provide useful context for understanding possible sources behind the observed and estimated indicators. From an economic and ecological viewpoint, PM2.5 and PM10 pollution pressures affect urban air quality, public health, worker productivity, healthcare expenses, and city management.

Therefore, cleaner transport, better industrial monitoring, control of construction dust, regular road cleaning, and green urban planning are key policy directions for both cities. Overall, combining numerical datasets with photographic field observations links particulate matter indicators to real urban processes and supports a clearer understanding of air pollution in the context of sustainable urban development.

Conclusion

This study examined the factors related to PM2.5 and PM10 air pollution in Sumgayit and Almaty. It used numerical datasets and photographic field observations. The results indicate that Almaty experiences more seasonal changes, with higher levels of particulate matter in the colder months. In contrast, Sumgayit shows relatively stable PM2.5 levels and estimated PM10 ranges. Key contributors in both cities include industrial activity, traffic congestion, construction dust, fog and smog conditions, and various urban environmental factors.

The study shows that combining air quality data with visual field evidence gives a solid basis for understanding urban air pollution. Cleaner transport, better industrial monitoring, dust control, and green urban planning are suggested as important policies to reduce particulate matter pollution and promote sustainable urban development.

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The Strategic Role of Technoparks in Education and Economic Development: A Step Towards the Future

Madina Allahverdiyeva

Abstract. *This article analyzes the strategic role of technoparks in strengthening the relationship between higher education institutions and economic development. Technoparks are recognized as important innovation infrastructures that facilitate the transformation of scientific knowledge into practical and market-oriented solutions. By integrating research, education, and entrepreneurship, they create an environment where innovative ideas can be developed, tested, and commercialized.*
Within the framework of higher education, technoparks provide students and researchers with opportunities to participate in applied research projects and gain practical experience in technological development and innovation management. Such environments encourage interdisciplinary cooperation and support the emergence of creative solutions to contemporary economic and technological challenges.
In addition, technoparks contribute to the growth of innovative enterprises and startups by offering access to technological infrastructure, professional mentorship, and cooperation with industrial partners. This interaction strengthens knowledge transfer processes and promotes the effective use of academic research in industry.
From a broader perspective, technoparks play a significant role in regional and national development by supporting high-technology sectors, stimulating investment in innovation, and expanding employment opportunities for highly qualified specialists. The article also discusses current trends and challenges in the development of technopark ecosystems and evaluates their long-term impact on the formation of sustainable innovation systems and competitive knowledge-based economies.

Keywords: *Technopark, education, economic development, university–industry collaboration, startup and entrepreneurship*

Introduction

In the contemporary era, the emergence of knowledge- and technology-based economies encourages states and societies to invest more substantially in education and innovation. Within this context, technoparks—centers integrating research, technology, education, and entrepreneurial activities—hold strategic importance. On one hand, technoparks facilitate the realization of universities' scientific potential; on the other, they stimulate the innovative development of the economy.

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The function of technoparks is not limited to supporting technological startups; they also play a significant role in training young professionals, fostering collaboration between educational institutions and the industrial sector, and contributing to regional economic development. Consequently, technoparks are considered essential structures bridging education and the economy. For this reason, this article examines the strategic role of technoparks in education and economic development through a comprehensive analysis divided into the following sections.

1. Technopark of Nakhchivan State University:

A Platform for Scientific and Innovative Development

In the modern world, technoparks are regarded as key mechanisms for establishing innovation-driven economies, strengthening university–industry collaboration, and forming startup ecosystems. In Azerbaijan, large-scale projects in this direction are being implemented. In regions with unique geographical characteristics, such as Nakhchivan, strategic steps aimed at advancing new technologies are particularly significant. In this context, the establishment of the Technopark at Nakhchivan State University (NSU)represents not only the modernization of an educational institution but also a critical step toward shaping the region's innovative future (The Role of Technoparks in Education and Economic Development, 2023).

The primary objectives of the technopark include enhancing students' practical skills, supporting scientific research, promoting the development of startups, and invigorating the local economy.

Development

The NSU Technopark is a multi-level complex combining research laboratories, innovation centers, and business incubators. Its infrastructure encompasses specialized divisions in nanotechnology, biotechnology, programming, automation, artificial intelligence, and electronics. This structure enables students and researchers to engage in multidisciplinary activities.

Business incubators and co-working spaces play a vital role in the technopark's innovation ecosystem by supporting early-stage startup projects, providing mentorship, facilitating prototyping, and enabling commercialization. Collaboration with companies such as Microsoft and Cisco further ensures the transfer of international expertise to the regional scientific environment.

The biotechnology and agro-oriented laboratories of the technopark foster agricultural innovations aligned with Nakhchivan's economic and geographic characteristics. Research conducted in these areas aims to optimize the utilization of regional resources.

The NSU Technopark functions as a strategic center that strengthens the university's scientific potential, drives regional socio-economic development, and supports innovation-oriented human resource training. Its activities accelerate the practical application of scientific research, the integration of technological solutions into production, and the formation of a startup ecosystem. Accordingly, the technopark contributes significantly both to the modernization of higher education and to the region's innovative development strategy (International Symposium on the Role of Technoparks in Education and Economic Development, 2023).

2. The Role of Technoparks in the Education System

University–Technopark Collaboration

Technoparks closely collaborate with universities to create new opportunities in education. University-based technoparks consolidate research activities, startup ideas, and practical applications within a single structure.

For instance, the Baku Engineering University Technopark (Azerbaijan) operates structurally to strengthen university–industry collaboration. This arrangement enables students and faculty members to develop scientific research not only theoretically but also in terms of commercialization, patenting, and addressing real industrial needs.

Technoparks play an indispensable role in modernizing the education system and preparing a workforce aligned with labor market demands. They provide students and young researchers with opportunities to test theoretical knowledge in real-world projects, making education practice-oriented. Additionally, technoparks bring higher education institutions and industry together, fostering an innovation culture. Here, students and young scholars can transform their innovative ideas into business projects and receive mentorship and investment support (The Role of Technoparks in Education and Economic Development, 2023; Ahmadova, Abdulhasanova, Abdulhasanov, Nuriyeva, & Mohsumova, 2026).

In summary, technoparks facilitate the practical application of theoretical knowledge and promote the development of creative, innovation-oriented young professionals.

Practical Environment and Startup Opportunities for Students

Technoparks provide students with practical opportunities beyond theoretical training, including laboratory work, realization of startup ideas, and participation in incubator and accelerator programs. This allows students to apply their knowledge directly to real-world contexts. For example, research conducted in Indonesia indicates that vocational high schools associated with technoparks have significantly improved students' practical skills, teamwork, and critical thinking. (Gomes, Lopes, Ferreira,& Oliveira, 2023).

Commercialization of Research and Technology Transfer

Technoparks support the commercialization and technology transfer of scientific outcomes generated within educational institutions. Thus, the education system produces not only "knowledge" but also "products and services derived from knowledge."
For instance, according to international documents, "Technoparks provide infrastructures for technology transfer and commercialization of new knowledge between academics, research institutes, and industry." (Albahari, Klofsten, & Rubio-Romero, 2018).

Contribution to Modern Educational Models

The activities of technoparks promote modern educational models such as university–industry collaboration, innovation ecosystems, and startup culture in education. For example, a Turkish technopark's definition notes: "In a model uniting university, industry, and state, technoparks play a leading role in establishing an innovation-based economy." This transforms educational institutions from passive knowledge centers into active, innovative spaces where students and faculty focus on solving real-world problems (International Experience in Establishing Technoparks, 2017, p. 68).

3. Impact of Technoparks on Economic Development

Role in Building an Innovation-Based Economy

Technoparks serve as hubs where high-tech firms, new business models, and R&D activities converge. For example, in Turkey, more than 5,000 firms operate through technoparks, generating approximately $4 billion in exports. Therefore, technoparks are vital not only for education but also for enhancing the competitiveness of the economy (Ahmadova, Abdulhasanova, Abdulhasanov, Nuriyeva, & Mohsumova,2026).

Development of Small and Medium Enterprises (SMEs)

Technoparks create a favorable environment for SMEs, offering subsidies, tax exemptions, R&D support, and incubation programs. In Azerbaijan, resident companies in technoparks receive temporary exemptions from income tax. This facilitates the production of innovative goods and services, access to new markets, and business growth.

Job Creation and Regional Development

Technoparks generate new, high-skilled, and higher-paying jobs, reducing regional unemployment and mitigating brain drain. In Turkey, over 78,000 R&D, design, and other staff work in technoparks. Additionally, technoparks contribute to regional economic diversification, guiding areas traditionally dependent on conventional industries toward new technology sectors (Ahmadova,Abdulhasanova, Abdulhasanov, Nuriyeva, & Mohsumova,2026;Gomes, Lopes, Ferreira, & Oliveira,2023).

Economic Diversification and International Competitiveness

Through technoparks, access to both domestic and international markets increases. Technopark-produced technology-based products in Turkey have boosted exports. Simultaneously, the economy shifts from raw materials toward knowledge- and technology-intensive sectors, contributing to sustainable long-term development (Ahmadova, Abdulhasanova, Abdulhasanov,Nuriyeva, & Mohsumova,2026).

In summary, technoparks have multifaceted economic impacts:

1. They create jobs and foster startup formation.
2. They commercialize scientific research, increasing local production and export potential .
3. They attract new investments, playing a crucial role in regional economic growth.

In the digital economy era, technoparks are a cornerstone of state innovation strategies, advancing not only technology but also the development of the knowledge economy.

4. Technoparks as a Bridge Between Education and the Economy

Knowledge Economy Model

Technoparks are fundamental elements of the knowledge economy: knowledge generated in educational institutions and research centers is transformed into economic value through startups and entrepreneurial structures within technoparks. This process ensures not only knowledge production but also its economic utilization. Studies indicate that technoparks strengthen university–industry linkages, promoting the transition from “knowledge” to “value” (The Role of Technoparks in Education and Economic Development, 2023; Ahmadova, Abdulhasanova, R., Abdulhasanov, T., Nuriyeva, & Mohsumova, 2026; Albahari, Klofsten, & Rubio-Romero, 2018). According to the “Triple Helix” model, universities, technoparks, and the industry sector must interact, with technoparks providing the physical and institutional platforms for such engagement.

University–Industry Collaboration

Technoparks act as direct bridges between universities and industry. For example, Baku Energy University has established a “Technology Transfer Center” within its technopark to bring faculty and student projects to industry and support startups.

Additionally, in India, the Technopark Technology Business Incubation Centre (TTBIC) has developed platforms such as “Industry Connect” and “Knowledge Network” to strengthen student–industry connections (Gomes, Lopes, Ferreira,& Oliveira, 2023).These examples show that technoparks are not merely physical spaces; they facilitate contracts, joint projects, internships, and technology transfer mechanisms between educational institutions and industry.

Transforming Educational Knowledge into Economic Value

At technoparks, students, faculty, and researchers have opportunities to bring their projects, prototypes, and startups to market. Consequently, the education system encompasses not only learning but also creation and commercialization. Products developed by technopark researchers are already being exported, generating economic revenue for universities and regions. Thus, technoparks play a critical role in transforming knowledge into economic assets (The Role of Technoparks in Education and Economic Development", 2023; Ahmadova, Abdulhasanova, Abdulhasanov, Nuriyeva, & Mohsumova, 2026; Albahari, Klofsten, & Rubio-Romero,2018).

Creating Regional and Sectoral Synergy

Technoparks also operate in regions, promoting local economic and educational development. Through university–technopark–industry collaboration, specialized workforce is trained, startup infrastructures are developed, and the local economy benefits through residencies, jobs, and new technologies. Moreover, technoparks establish sector-specific ecosystems in IT, engineering, biotechnology, and other areas, supporting sectoral diversification. This synergy—the integration of education, knowledge, innovation, and economic activity—is one of technoparks' strongest assets.

Conclusion

Technoparks serve as a bridge between education and the economy, transforming knowledge and innovation into economic value. Research conducted at universities is applied to industry through technoparks, leading to the creation of new products and services. International experiences indicate that technoparks strengthen university–industry collaboration and support regional development. Azerbaijan has made progress in this area; for example, the White City Technopark and the Technology Transfer Center of Baku Engineering University represent significant initiatives.

The NSU Technopark is emerging as a strategically important innovation center for the region. This project not only expands the university's teaching and research capacities but also provides students with practical work experience, supports startup growth, and enables scientific partnerships for companies. Once fully operational, the technopark is expected to elevate the level of scientific research, implement new technologies, and effectively harness the creative potential of youth in the Nakhchivan Autonomous Republic. Consequently, this project will serve as a cornerstone for long-term and sustainable development in both education and the economy.

Recommendations

- **Strengthening Technopark Infrastructure:** Establishing modern infrastructure to support startup development and attract international investors.
- **Enhancing Collaboration with Educational Institutions:** Strengthening cooperation between universities and technoparks to accelerate research application and foster new innovative products.
- **Establishing Regional Technoparks:** Developing technoparks across Azerbaijan to support regional development and enable workforce specialization.
- **Improving Tax and Legal Regulations:** Enhancing tax incentives and legal frameworks for companies operating in technoparks to promote innovation.
- **Promoting an Innovation Culture:** Increasing societal interest in innovation and fostering creative thinking in educational institutions and technoparks for long-term development.

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Transformational Leadership and Strategic Human Resource Management as Enablers of Change in a Dynamic Business Environment

Aytan Imanova

Abstract.*This article examines the interaction between transformational leadership and strategic human resource management in enabling organizational change in a dynamic business environment. The study is based on the assumption that organizations can no longer rely only on formal structures, administrative HR procedures, or short-term managerial reactions. Under conditions of digitalization, competitive pressure, changing employee expectations, and organizational uncertainty, leadership behavior and HRM systems become central instruments for building change readiness. The scientific novelty of the article lies in interpreting transformational leadership and strategic HRM as mutually reinforcing mechanisms of organizational transformation in the Azerbaijani business context. The findings show that training and career development activities are positively associated with HRM effectiveness, while learning motivation and training opportunities demonstrate the strongest explanatory role in the regression model. The article concludes that Azerbaijani companies need integrated HR systems that develop employees' abilities, strengthen motivation, and create real opportunities for participation in change.*

Keywords: *transformational leadership, strategic HRM, organizational change, SOCAR, training, career development, dynamic business environment*

Introduction

The contemporary business environment is marked by volatility, uncertainty, digital acceleration, global competition, and continuous changes in the labor market. These conditions force organizations to reconsider how they plan, lead, and develop their people. In previous periods, companies could often operate through relatively stable strategies and incremental improvements(Aksu, 2022; Gerçek, 2023). In the current environment, however, stability is no longer sufficient(Boselie, Dietz, & Boon, 2005; Combs et al., 2006). Organizations must develop the internal capacity to learn quickly, interpret external signals, and adapt their structures, processes, and workforce capabilities (Horney et al., 2010; Sanders et al., 2024).

Research

They are created through leadership behaviors and HRM systems that mobilize employee knowledge, commitment, and participation (Ulrich et al., 2024; Apascaritei & Elvira, 2022; Boselie et al., 2005; Maity, 2019).

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Table 1
Results of reliability analysis of the survey dimensions

Dimensions	Item number	Cronbach Alpha (alpha)
Training and career in human resource management	30	0.94
Training opportunities received	4	0.62
Management support for training	5	0.89
Co-workers' support for training	5	0.60
Learning motivation in training programs	5	0.94
Expected individual gains from training	6	0.85

Source: Compiled by the author based on the SOCAR employee survey results.

This is important because strategic HRM cannot function effectively if training access is perceived as unclear or uneven (Noe et al., 2014; Maity, 2019).

Table 2
Standard deviations and arithmetic means of training and career dimensions

Dimension	Standard deviation	Arithmetic mean
Training opportunities	0.80	3.10
Managerial support for training	0.92	3.73
Co-worker support for training	0.61	3.62
Learning motivation in training programs	0.83	4.16
Expected individual gains from training	0.81	3.82
Career expectations related to training	0.91	3.44

Source: Compiled by the author based on the SOCAR employee survey results.

Table 3
Selected highest and lowest mean values from the survey results

Survey area	Highest evaluated statement	Mean	Lowest evaluated statement	Mean
Training opportunities	The company determines the policy on the number and type of trainings.	3.52	I have advance information about future trainings.	2.31
Managerial support	My supervisor treats mistakes as learning experiences.	4.03	My manager supports me in mastering training knowledge and skills.	3.59
Co-worker support	My colleagues help me when I need support in my work.	3.91	I established good friendships as a result of trainings.	3.22
Learning motivation	I am ready to make the effort needed to develop my skills.	4.30	I tend to learn more from training programs than others.	4.02
Career expectations	Training helps me achieve my career goals.	3.76	Training helps me increase my salary.	2.68

Source: Compiled by the author based on the SOCAR employee survey results.

The selected item results show a practical gap between learning motivation and career expectations. Employees are motivated to learn and generally see training as useful for professional growth(Aksu, 2022; Gerçek, 2023).

Table 4
Correlation values between selected variables

Relationship	Correlation coefficient (r)	Significance	Interpretation
Training opportunities and total training-career scale	0.566**	$p < 0.01$	Moderate positive relationship
Managerial support and total training-career scale	0.781**	$p < 0.01$	Strong positive relationship
Co-worker support and total training-career scale	0.741**	$p < 0.01$	Strong positive relationship
Learning motivation and total training-career scale	0.835**	$p < 0.01$	Strong positive relationship
Expected individual gains and total training-career scale	0.887**	$p < 0.01$	Very strong positive relationship
Career expectations and total training-career scale	0.786**	$p < 0.01$	Strong positive relationship
Training-career activities and HRM effectiveness	0.695**	$p < 0.01$	Strong positive relationship

Source: Compiled by the author based on the SOCAR employee survey results

These results support the AMO logic: employees contribute more effectively when they have the ability to learn, the motivation to improve, and the opportunity to apply newly acquired skills (Combs et al, 2006; Subramony, 2009)

Table 5
Results of regression analysis on HRM effectiveness

Independent variable	Beta	Standard error	t value	Sig.	VIF
Training opportunities	0.217*	0.074	2.793*	0.007	1.498
Management support for training	-0.021	0.076	-0.222	0.827	2.058
Co-worker support for training	0.102	0.106	1.193	0.237	1.787
Learning in training and career programs	0.523*	0.094	5.135*	0.000	2.579
Motivation	0.256*	0.112	2.169*	0.034	3.466
Expected individual gains	-0.179	0.078	-1.914	0.058	2.173

Source: Compiled by the author based on the SOCAR employee survey result.

The regression results highlight a central practical conclusion: the effectiveness of HRM depends not only on whether training exists, but also on whether employees experience it as a real learning and career mechanism. The largest beta value belongs to learning in training and career programs (Deng, et al., 2023; Potocnik 2018, Combs et al., 2006). This means that when employees perceive training as a meaningful learning process, their evaluation of HRM effectiveness increases substantially. Motivation also has a positive effect, confirming that HRM systems must encourage employees to invest effort in their own development (Noe et al., 2014; Maity, 2019).

Transformational leadership is directly relevant to this process. Leaders can reduce resistance to change by communicating a clear purpose, supporting experimentation, and treating mistakes as learning opportunities (Deng et al., 2023; Khaw et al., 2022). This requires competency-based recruitment, systematic training needs analysis, transparent career paths, digital HR analytics, and stronger cooperation between companies, universities, and training institutions (Radonjić, Duarte, & Pereira, 2024; Raman, Venugopalan, & Kamal, 2024).

Conclusion

The study shows that transformational leadership and strategic human resource management are closely connected mechanisms of organizational change. In a dynamic business environment, organizations need leaders who can create vision, motivate employees, encourage learning, and reduce fear of change. At the same time, they need HRM systems that transform this leadership direction into practical mechanisms such as recruitment, training, performance management, career planning, employee participation, and talent development (Ulrich et al., 2024).

On the basis of the research results, the following recommendations can be proposed:

1. HR departments should participate in strategic planning and identify future skill needs before transformation programs are implemented.
2. Training programs should be supported by mentoring, coaching, feedback, and practical project-based learning.
3. Career development systems should clearly explain the connection between competencies, training results, promotion, and internal mobility.
4. Managers should be trained in transformational leadership behaviors, especially vision communication, employee support, constructive feedback, and change facilitation.
5. Digital HR analytics should be used to monitor workforce capabilities, employee expectations, and the effectiveness of development programs.
6. Azerbaijani companies should align HRM systems with national goals such as digital transformation, professional skill development, inclusive employment, and sustainable organizational growth.

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Multi-Criteria Decision Making and Strategic Decision Qualityin Management: An Integrated AHP-TOPSIS Approach

Farahim Hajiyev

Abstract. *This article examines the role of multi-criteria decision making in improving strategic management decisions under uncertainty, competing priorities, and institutional risk. The study focuses on the integrated use of the Analytic Hierarchy Process and TOPSIS as a decision-support framework for strategic investment evaluation. The central argument is that managerial choices cannot be justified only through intuition or a single financial indicator, because real strategic alternatives must be assessed through return, risk, liquidity, strategic fit, capital requirement, and regulation or compliance at the same time. The scientific novelty of the article lies in adapting the AHP-TOPSIS logic to a strategic decision problem in the Azerbaijani financial sector and presenting it in a transparent article format. The findings show that risk is the dominant criterion in the decision hierarchy, while expected return and strategic fit follow as important supporting priorities. The TOPSIS results indicate that the most appropriate alternative is the one with the most balanced performance across all criteria, not simply the alternative with the highest isolated return. The article concludes that MCDM methods can strengthen decision quality by making managerial priorities measurable, consistent, and easier to defend.*

Keywords: *multi-criteria decision making, AHP, TOPSIS, strategic management, investment decision, decision quality, Azerbaijan financial sector*

Introduction

Contemporary organizations operate in an environment where management decisions are increasingly affected by uncertainty, regulatory pressure, scarce resources, and the need to balance short-term performance with long-term sustainability. In such conditions, strategic decisions become difficult because managers must compare alternatives that do not perform equally across all evaluation dimensions. An investment option may promise a high return, but it may also involve excessive risk, weak liquidity, or a compliance burden. Another option may be less profitable but more stable, easier to implement, and more consistent with institutional strategy. This complexity shows why modern management needs structured analytical tools rather than purely intuitive judgment (Belton & Stewart, 2002; Goodwin & Wright, 2014). Multi-Criteria Decision Making methods are especially relevant for this type of problem because they allow decision makers to evaluate several criteria simultaneously and to convert expert judgments into a traceable decision logic.

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Within the broad MCDM family, AHP and TOPSIS are among the most widely used approaches. AHP helps determine the relative importance of criteria through pairwise comparisons, while TOPSIS ranks alternatives according to their closeness to the ideal solution and distance from the negative ideal solution. When these methods are integrated, they create a practical framework for strategic evaluation: priorities are first measured, then alternatives are ranked according to these priorities (Saaty, 1992; Hwang & Yoon, 1981).

Research

The research is based on a strategic investment decision scenario reflecting the logic of management practice in the Azerbaijani financial sector. Because financial institutions operate under risk-sensitive and compliance-oriented conditions, the decision model was structured around six criteria: expected return, risk level, liquidity, strategic fit, capital requirement, and regulation/compliance impact. These criteria were selected because they jointly represent both financial attractiveness and institutional suitability. The model therefore avoids a narrow view of strategy and treats decision quality as the outcome of a balanced multi-dimensional assessment (Mardani et al., 2015; Zavadskas et al., 2014).

Table 1
Strategic investment criteria and evaluation directions

Criterion	Direction	Evaluation logic
K1 Expected return	Benefit	Higher expected return increases financial attractiveness.
K2 Risk level	Cost	Lower risk is preferred because it reduces uncertainty and potential loss.
K3 Liquidity	Benefit	Higher liquidity supports flexibility and faster resource conversion.
K4 Strategic fit	Benefit	Higher alignment strengthens consistency with organizational priorities.
K5 Capital requirement	Cost	Lower capital need reduces resource pressure and opportunity cost.
K6 Regulation/compliance	Benefit	Higher compliance quality improves governance and regulatory soundness.

Source: Compiled by the author based on the MCDM application model.

The criteria in Table 1 show that the decision problem contains both benefit and cost dimensions. This distinction is essential for the TOPSIS stage because the ideal solution is not defined by maximizing every indicator. Some criteria, such as return and compliance, should be maximized, whereas risk and capital requirement should be minimized. In management practice, this logic reflects the real nature of strategic choices, where a strong alternative must combine opportunity with control (Triantaphyllou, 2000; Zavadskas &Turskis, 2011).

Table 2

AHP results: criteria weights in the strategic decision model

Criterion	Weight (w_i)	Percentage
K2 Risk level	0.4226	42.26%
K1 Expected return	0.1908	19.08%
K4 Strategic fit	0.1908	19.08%
K6 Regulation/compliance	0.0889	8.89%
K3 Liquidity	0.0704	7.04%
K5 Capital requirement	0.0365	3.65%
Total	1.0000	100%

Source: Compiled by the author based on the AHP pairwise comparison results.

The AHP results indicate that risk is the most influential criterion in the modeled decision hierarchy. This outcome is consistent with the nature of strategic financial decisions, where uncertainty and possible loss often shape managerial preferences more strongly than return alone. Expected return and strategic fit receive equal weights, which means that financial performance and long-term institutional alignment are treated as complementary priorities. The lower weight of capital requirement does not imply that resource use is irrelevant; rather, it shows that decision makers in the modeled scenario give greater importance to strategic security and risk control than to the isolated cost of capital (Saaty, 1992; Guitouni& Martel, 1998).

Table 3

AHP consistency test results

Metric	Value	Interpretation
Number of criteria (n)	6	Six decision criteria were compared.
Maximum eigenvalue (λmax)	6.1980	Close to n, indicating acceptable comparison structure.
Consistency index (CI)	0.0396	Low internal inconsistency.
Random index (RI)	1.24	Standard RI value for n = 6.
Consistency ratio (CR)	0.0319	CR < 0.10, therefore judgments are acceptable.

Source: Compiled by the author based on the AHP consistency calculation.

The consistency ratio confirms that the pairwise comparisons are logically acceptable. This point is important because AHP does not remove human judgment from management decisions; instead, it organizes and tests that judgment. When the consistency ratio remains below the generally accepted threshold of 0.10, the resulting weights may be used in the next stage with greater confidence. In this sense, consistency analysis acts not only as a mathematical control but also as a managerial discipline mechanism, encouraging decision makers to review priorities when contradictions appear (Saaty, 1992; Goodwin & Wright, 2014).

Table 4
TOPSIS decision matrix used for ranking strategic alternatives

Alternative	K1 Return	K2 Risk	K3 Liquidity	K4 Fit	K5 Capital	K6 Compliance
A1	70	30	85	60	40	90
A2	65	35	75	70	50	85
A3	90	80	60	80	70	70
A4	80	50	70	75	55	80

Source: Compiled by the author based on the TOPSIS scenario calculations.

The decision matrix presents four alternatives evaluated under the same six criteria. Alternative A3 has the highest return value, but it also has the highest risk and capital requirement. This demonstrates why a one-dimensional return-based ranking would be misleading. The TOPSIS method is useful precisely because it considers the entire profile of each alternative and evaluates whether high performance in one dimension is balanced by acceptable performance in the others (Hwang & Yoon, 1981; Koksalan et al., 2011).

Table 5
TOPSIS final results: relative closeness coefficients and ranking

Rank	Alternative	Relative closeness (C_i)	Managerial interpretation
1	A1	0.8474	Best balanced profile with low risk and strong liquidity/compliance.
2	A2	0.8205	Close to the leading option; strong strategic fit and acceptable risk.
3	A4	0.6011	Moderate option with balanced but weaker ideal closeness.
4	A3	0.1683	High return is outweighed by high risk and capital requirement.

Source: Compiled by the author based on the TOPSIS ranking results.

The final TOPSIS ranking shows that A1 is the most suitable alternative, followed closely by A2. The most important managerial implication is that the best option is not necessarily the alternative with the highest return. A3, despite its strong return value, ranks last because its risk and capital requirement are unfavorable under the weighted decision logic. This result supports the main argument of the article: strategic management decisions require balanced evaluation, and MCDM methods provide a transparent way to justify that balance (Mardani et al., 2015; Zavadskas et al., 2014).

The integrated AHP-TOPSIS framework also strengthens the accountability of board-level and committee-level decisions. AHP makes it possible to explain why one criterion receives more importance than another, while TOPSIS explains why one alternative is preferred in the final ranking. Together, the two methods create a chain of reasoning from managerial priorities to measurable decision outcomes. Such a framework is valuable in financial organizations because investment choices must be defensible not only internally but also in relation to compliance, governance, and stakeholder expectations (Belton & Stewart, 2002; Sharda, Delen, & Turban, 2021).

However, the application of MCDM in organizations should not be treated as a mechanical exercise. The quality of the result depends on the relevance of criteria, the reliability of data, the competence of experts, and the neutrality of the evaluation process. Incomplete data can distort alternative scores, while decision-maker bias can affect pairwise comparisons. Therefore, successful implementation requires a clear decision problem, transparent criterion definitions, updated data sources, and sensitivity analysis to test whether the ranking changes under different weighting assumptions (Liu et al., 2019; Siksnelyte-Butkiene et al., 2020).
From a practical perspective, the model can be adapted for investment committees, project prioritization, supplier selection, technology adoption, risk-based portfolio evaluation, and other strategic decisions. Its main advantage is that it transforms dispersed managerial opinions into an organized analytical structure. At the same time, the model remains understandable enough for practitioners because the logic of weighting and ranking can be communicated through tables, coefficients, and criterion explanations rather than through overly abstract formulas.

Conclusion

The study shows that multi-criteria decision-making methods are effective tools for improving strategic decision quality in management. In complex organizational environments, decisions are rarely based on one criterion, and alternatives usually involve trade-offs among return, risk, liquidity, strategic fit, capital requirement, and compliance. The integrated AHP-TOPSIS framework used in this article makes these trade-offs visible and measurable. AHP identifies the relative importance of criteria, while TOPSIS transforms those weighted priorities into a final ranking of alternatives.

The results demonstrate that risk is the dominant criterion in the modeled strategic investment decision, followed by expected return and strategic fit. This finding reflects a prudent management logic in which stability, uncertainty control, and institutional alignment are prioritized together with financial attractiveness. The consistency result confirms that the criterion weights are logically acceptable, while the TOPSIS ranking shows that the strongest alternative is the one with the most balanced profile rather than the highest isolated return.

On the basis of the research results, the following recommendations can be proposed:
1. Organizations should define decision problems clearly before applying any MCDM model.
2. Criteria should be selected according to strategic relevance, measurability, and comparability.
3. AHP should be used to make managerial priorities explicit and to test consistency in judgments.
4. TOPSIS should be applied when alternatives need to be ranked according to balanced overall performance.
5. Decision makers should check the sensitivity of results when criterion weights or scores change.
6. Financial institutions should integrate MCDM logic into governance, risk, and investment committee procedures.

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Data-Driven Segmentation of the Construction Products Market: A Practical Marketing Application Model

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Abstract. *The construction products market is usually managed through product categories such as cement, dry mixes, ceramic tiles, insulation, paints, pipes, timber, and finishing materials. However, this approach does not fully explain why different customers buy the same product for different reasons. A household renovator may search for a reliable price and simple advice, while a contractor may value delivery speed, credit terms, and stable stock availability. This article proposes a data-driven segmentation model for improving marketing decisions in the construction products market. The study uses a conceptual IMRAD design based on secondary literature, B2B marketing logic, and practical market observation. The proposed model combines transaction data, customer type, purchase frequency, project scale, technical requirements, and channel preference. The results identify five actionable segments and connect each segment with suitable product, pricing, channel, communication, and service decisions. The article argues that segmentation should not be treated as a one-time classification exercise. It should become a closed-loop management tool supported by customer relationship management, sales dashboards, feedback from sales teams, and periodic revision of segment profitability. The findings can help construction product distributors, manufacturers, and retailers build more precise offers, reduce marketing waste, and strengthen long-term customer loyalty.*

Keywords: *construction products market, market segmentation, B2B marketing, customer relationship management, marketing strategy, pricing, distribution channels*

Introduction

The construction products market is complex because it serves both professional and non-professional buyers. A bag of cement, a box of ceramic tiles, or a roll of insulation may be bought by a household owner, a small repair team, a large contractor, a designer, a developer, or a public procurement unit. Each buyer evaluates value differently. Some customers compare only the visible price, while others calculate total project cost, warranty risk, delivery reliability, and technical compatibility.

Traditional segmentation in many construction product firms is limited to categories such as "retail customers," "wholesale customers," or "corporate clients." This classification is useful for accounting, but it is too broad for marketing decisions. It does not show which customers need credit support, technical consulting, architect recommendations, or digital promotions. Modern marketing theory emphasizes that market segments must be measurable, accessible, substantial, differentiated, and actionable (Kotler & Keller, 2016).

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The problem addressed in this article is the weak connection between segmentation analysis and real marketing application. Many firms collect sales data, but they do not transform it into targeted decisions. As a result, the same discounts, advertisements, product bundles, and service conditions are offered to very different customers. The purpose of the article is to develop a practical segmentation model for the construction products market and to explain how this model can improve pricing, assortment planning, channel selection, communication, and after-sales service.

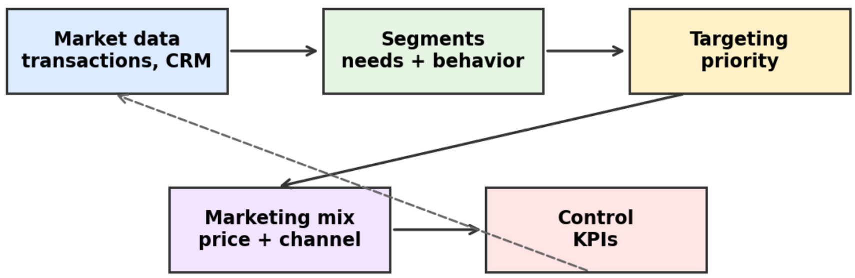

Figure 1
Closed-loop segmentation logic for construction products

The article uses a conceptual research design based on marketing segmentation theory, B2B marketing principles, customer journey logic, and practical features of the construction products market. This method is suitable because the aim is not to measure one company only, but to build a transferable model that can be adapted by manufacturers, distributors, and retailers.

The proposed segmentation procedure has five stages: data audit, variable selection, segment formation, segment evaluation, and marketing application. A company should collect sales invoices, customer profiles, purchase frequency, average order value, payment discipline, return rates, delivery data, complaint history, and product categories. The most useful segmentation variables include project size, buyer role, technical knowledge, urgency, price sensitivity, credit need, channel preference, and dependence on professional recommendations.

The article separates B2C and B2B logic. Household buyers usually need trust, clear explanation, visible samples, and fast problem solving. B2B buyers usually need stable supply, technical documentation, project-based pricing, credit conditions, and dependable delivery. However, the border is not always strict. A small repair team may behave like a household customer in digital search but like a B2B buyer in repeated purchasing.

The model identifies five actionable segments. The first is value-driven household renovators. These customers buy for apartment repair, small house renovation, or seasonal improvement. They are price-sensitive, but they also fear poor-quality materials. Effective marketing tools for this segment are simple comparison, visible price bundles, installation advice, and short educational content. The second segment is quality and design seekers. They value finishing materials, showroom experience, samples, brand trust, and visual communication.

The third segment is contractor volume buyers, including repair teams and subcontractors. Their main needs are stable stock, quick loading, delivery accuracy, flexible payment terms, and volume discounts. A contractor card, fast ordering channel, and dedicated account manager can increase retention. The fourth segment is specification-driven professionals such as architects, engineers, and designers. They require certificates, technical catalogues, samples, training, and professional trust.

The fifth segment is institutional and project procurement. These buyers include developers, large contractors, and public or corporate procurement units. Their decisions depend on tender requirements, delivery schedules, legal documentation, risk reduction, and transparent pricing. For this segment, marketing must cooperate closely with finance, logistics, legal, and technical departments.

Table 1
Practical segment-action matrix for construction product marketing

Segment	Main need	Recommended action	Key indicator
Household renovators	Affordable and safe choice	Bundles, advice cards, comparison	Conversion rate
Quality seekers	Design and brand confidence	Showroom, samples, visual content	Average basket value
Contractor buyers	Speed, stock, credit	Contractor card, fast ordering	Repeat purchase rate
Spec-driven professionals	Technical certainty	Catalogues, training, certificates	Specification share
Institutional procurement	Reliability and risk control	Project offers, documentation	Tender win rate

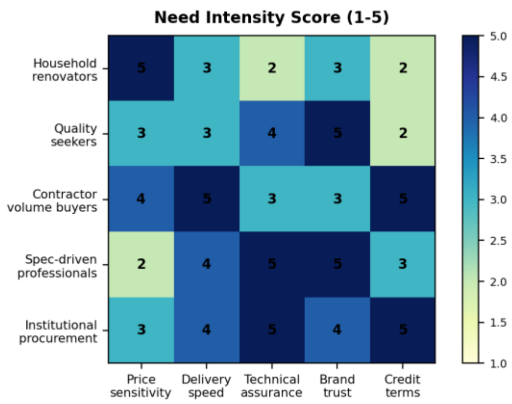

Figure 2
Illustrative segmentation heat map for marketing decisions

The model shows that marketing improvement starts when the company stops treating all buyers as equal. Price discounts are powerful for household renovators and contractor buyers, but they may weaken the premium image for quality seekers. Technical seminars are useful for specification-driven professionals, while institutional buyers often need a formal documentation package more than creative advertising. Segmentation also supports disciplined inventory decisions because each customer group requires a different depth of assortment.

The proposed model supports the idea that segmentation is not only a research activity, but also a management system. In the construction products market, customer value is created through a combination of material quality, information, delivery, trust, and financial convenience. A company that understands these differences can design a more precise marketing mix. This is consistent with the broader marketing view that segmentation should guide targeting and positioning rather than remain a formal description of the market (Wedel & Kamakura, 2000).

One important implication is the need for customer relationship management. Construction product companies often have rich transaction data but weak customer profiles. A CRM system can connect purchase history with customer type, project information, sales manager notes, complaints, delivery records, and promotional response. When this information is structured, the company can identify high-value segments, inactive customers, cross-selling opportunities, and risky accounts.

Channel and pricing strategy should also be segment-based. Some customers want to visit a physical store because they need to compare colors or receive advice. Others prefer digital ordering, phone-based reordering, or direct communication with an account manager. Household renovators can receive package offers, contractor buyers can receive volume-based terms, professionals can receive project support, and institutional buyers can receive tender-based quotations. In B2B markets, relationship value and service reliability are often as important as the unit price (Hutt &Speh, 2012). The model has limitations. First, it proposes a conceptual framework and does not test one firm's confidential sales data. Second, segments may differ between regions because income level, construction activity, retail culture, and logistics conditions are not identical. Third, segmentation can become too complicated if a company creates many small groups that cannot be served differently. For practical use, four to six strong segments are usually more useful than dozens of narrow labels.

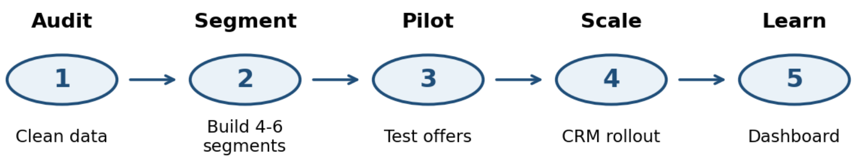

Figure 3
Five-stage implementation roadmap for marketing improvement

This article developed a practical model for optimizing segmentation in the construction products market and improving marketing application. The main conclusion is that segmentation should move beyond product categories and broad customer labels. The market should be understood through buyer needs, purchase behavior, project scale, technical expectations, channel preference, and financial requirements. Five segments were proposed: value-driven household renovators, quality and design seekers, contractor volume buyers, specification-driven professionals, and institutional procurement buyers.

Each segment requires a different marketing response. Effective segmentation influences assortment planning, price architecture, communication, distribution, technical support, and after-sales service. The best result is achieved when segmentation becomes a closed-loop process: data are collected, segments are formed, offers are tested, indicators are measured, and the model is updated. Future empirical research may test the model using survey data, customer interviews, and transaction databases from construction product retailers or distributors.

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