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ORIGINAL ARTICLE

Economic-Mathematical Assessment and Scenario Analysis of Agricultural Enterprise Efficiency in Kazakhstan

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Abstract
Improving the efficiency of agricultural enterprises in Kazakhstan requires a comprehensive accounting of production, financial, technological, and risk factors, since an increase in nominal output does not always reflect a real improvement in performance. The aim of this study is to develop an economic-mathematical model for the quantitative assessment and forecasting of the effective development of agricultural enterprises in Kazakhstan amid a growing innovation-driven economy. The information base was compiled using official statistical data of Kazakhstan for 2010-2025 on gross agricultural output, volume indices, gross harvest and yield of grain and leguminous crops, the introduction of water-saving technologies, and technical modernization of the industry. The methodological framework combines indicator standardization, entropy weighting, an innovation- and risk-augmented production function, an optimization formulation for resource allocation, and scenario-based forecasting of an integral efficiency index. The results showed that in 2019-2025, nominal agricultural output increased by 88.5%, while the real physical volume increased by about 24%. In 2025, the yield of grain and leguminous crops reached 16.31 c/ha, exceeding the previous year's level by 7.2%. In the innovation scenario, the profit of a conditional enterprise increases by about 28.6%, and the return on costs increases from 53.85% to 67.22%. By 2030, the value of the integral index in a given innovation scenario reaches 140.26 points versus 110.41 points in the inertial scenario. The results obtained can be used in intra-company planning, evaluation of investment decisions, and monitoring the effectiveness of agricultural policy.

KEYWORDS
Agriculture, Agricultural Enterprise, Agricultural Economy, Agribusiness, Innovation-Driven Economy, Production Efficiency, Business Efficiency

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1 | INTRODUCTION

Kazakhstan's agricultural sector is a geographically dispersed economic system in which food production, rural employment, export development, water security, and technological modernization are closely interconnected. According to the Bureau of National Statistics, the gross output of agriculture, forestry, and fisheries reached KZT 8,363.6 billion in 2024, while official government estimates indicate that gross agricultural output approached KZT 9.8 trillion in 2025 (Bureau of National Statistics, 2025). However, growth in nominal output alone is insufficient for assessing sectoral efficiency, as it may reflect price changes, favourable weather conditions, expanded cultivated area, or short-term resource exploitation.

For an agricultural enterprise, the quality of growth is more significant than its nominal magnitude: a sustainable increase in yield, a reduction in production costs, the rationalization of water consumption, an increase in technical readiness, a faster managerial response, and a reduction in uncertainty. Sustainable development requires higher yields, lower production costs, more efficient water use, improved technical readiness, faster managerial responses, and reduced uncertainty. In an innovation-driven economy, agricultural enterprises increasingly integrate field data, equipment monitoring, resource accounting, and financial information into a unified management system. Therefore, investments in digital technologies, water-saving systems, and machinery modernization should be assessed in terms of their measurable production and financial returns.

The problem addressed in this study is the absence of a unified applied model that integrates production, financial, technological, and risk-oriented indicators into a single forecasting system. In practice, isolated indicators dominate management: yield, profit, subsidies, sown area, gross harvest, investment, and debt. Each is important, but no single indicator can establish whether an enterprise is developing effectively. An increase in gross harvest, for instance, may be accompanied by rising water intensity, declining margins, and a deteriorating structure of working capital; conversely, a reduction in production costs may reflect insufficient fertilizer application and depress future yields. An economic-mathematical model is therefore required in which efficiency is defined as the dynamic integration of interrelated indicators and the forecast rests not on the mechanical extrapolation of the past but on a scenario-based assessment of the innovation cycle.

The aim of this study is to develop an economic-mathematical model for the quantitative assessment and forecasting of the effective development of agricultural enterprises in Kazakhstan amid a growing innovation-driven economy. To achieve this aim, the study systematizes theoretical approaches to modeling production efficiency; identifies variables relevant to the specific characteristics of the national agricultural sector; constructs an integrated index of effective development; presents a production-financial and optimization framework; performs calculation procedures based on open data and a hypothetical grain enterprise; and develops a scenario-based forecast through 2030. The scientific novelty lies in combining the production function, the entropy index, the optimization of resource allocation, and scenario forecasting within a single analytical framework

applicable to agricultural enterprises in Kazakhstan, and in validating the trend component of that framework against official physical-volume data.

2 | LITERATURE REVIEW

The theoretical foundation of this study draws on four complementary strands of the literature: production-function theory, the measurement of technical and allocative efficiency, forecasting methodology, and the applied economics of agricultural digitalization in Kazakhstan. Reviewing these strands together makes it possible to compare the methods, empirical designs, and principal findings on which existing studies rely; to identify the limitations they share; and to locate the specific research gap that the present model addresses.

The first strand concerns production functions, in which output is modelled as the result of interactions among labour, capital, and other production inputs. The classical Cobb–Douglas production function estimates output elasticities with respect to individual inputs and allows returns to scale to be assessed. Solow, in turn, interpreted technological change as a residual source of economic growth that cannot be explained solely by increases in labour and capital (Cobb & Douglas, 1928; Solow, 1957). A more flexible translog specification allows for interactions among inputs and variable production elasticities. Benedetti et al. (2019), for example, estimate a stochastic frontier production function using data from crop farms in Apulia, Italy. Their results reveal substantial differences in input-use efficiency across farms within the same region, with the greatest variation observed in fertilizer and irrigation use. This finding suggests that models based only on average production responses may conceal important farm-level heterogeneity. Laureti et al. (2021) extend this approach by incorporating a spatial lag into a stochastic frontier model to capture irrigation spillovers among neighbouring plots in Southern Italy. They demonstrate that water-use efficiency depends not only on individual farm decisions but also on the spatial organization of irrigation networks, a factor generally omitted from conventional production-function specifications.

These findings are highly relevant to Kazakhstan, where irrigated agriculture faces significant water constraints and agricultural regions differ substantially in resource availability and input-use conditions. Nevertheless, a stand-alone production-function approach primarily estimates the average or frontier response of output to production inputs and does not, by itself, integrate financial performance, risk, resource optimization, and forecasting into a unified decision-support framework.

The second strand addresses the measurement of efficiency and productivity. Data envelopment analysis, introduced by Charnes et al. (1978), evaluates the relative efficiency of comparable decision-making units using multiple inputs and outputs. Coelli et al. (2005) provide a broader methodological framework for distinguishing technical, allocative, and scale efficiency. This distinction is particularly important in agriculture: a farm may achieve high yields while maintaining an inefficient cost structure, use land productively but manage working capital poorly, or receive public support without generating sustainable investment re-

turns. Compared with parametric frontier methods, DEA does not require the prior specification of a production function. However, it is sensitive to measurement error and outliers and requires sufficiently comparable production units, while consistent enterprise-level data may be limited in Kazakhstan.

Recent empirical applications of stochastic frontier analysis allow a systematic cross-study comparison of efficiency levels, methodological choices, and the role of innovation and policy. Alemu et al. (2024), using a Cobb–Douglas stochastic frontier model for 35 sub-Saharan African countries over 2005–2020, report an average technical efficiency level of approximately 83 percent. Their findings indicate that labour and fertilizer inputs are positively associated with cereal production performance, whereas the expansion of cultivated land does not necessarily produce proportional efficiency gains. These results provide supporting evidence that agricultural growth cannot be explained solely by land expansion and that the productivity of variable inputs should also be considered.

Tleubayev et al. (2022) estimate a translog stochastic frontier model using farm-level data from 270 wheat producers in Kazakhstan and Russia. They obtain an average technical efficiency score of 74.4 percent, with almost one-fifth of farms operating below 60 percent efficiency. Their results indicate that fertilizer and other variable inputs have stronger output effects than land. They also find that managerial education, cooperative membership, and participation in insurance programmes are positively associated with efficiency, whereas subsidies show a negative association. These findings suggest that the effectiveness of agricultural support may depend not only on the amount of funding provided but also on its institutional design and the managerial capacity of recipients.

Parikoglou et al. (2024) employ a stochastic input-distance function for a panel of Irish dairy farms observed between 2008 and 2018. They construct a farm-level innovation index using k-means clustering of technology-adoption indicators and estimate that transition to a higher innovation state is associated with an average increase of 1.7 percentage points in technical efficiency. Their results also show that innovation affects individual production factors differently, indicating that its productivity effects are heterogeneous rather than uniform. The average efficiency score of approximately 90 percent nevertheless demonstrates that an efficiency gap remains even in a technologically advanced agricultural system.

Xie et al. (2024) analyse 443 small-scale mango producers in China using a digital agricultural technology service platform. They report positive associations between platform use, technical efficiency, and farm income, with improved information access and more precise input application acting as important transmission channels. Taken together, these studies suggest that agricultural efficiency depends not only on land scale and other conventional inputs but also on technology adoption, managerial capacity, institutional arrangements, and the quality of resource allocation. They further indicate that innovation should be represented through measurable adoption indicators and factor-specific channels rather than treated as a uniform technological shift.

To aggregate heterogeneous indicators into a composite index, the entropy

weight method is widely used to derive data-driven weights based on the degree of variation in individual indicators. Chen et al. (2023) compare several improved entropy-weighting methods in constructing a regional high-quality development index for Qinghai, China. Sun et al. (2023) combine entropy weighting with the G1 method and TOPSIS to assess the sustainable development of fresh agricultural product logistics enterprises. These studies justify the entropy-based weighting adopted here, but they also share a common limitation: entropy weighting is applied to static ranking or cross-sectional benchmarking rather than to a forward-looking production-financial model, so the resulting index describes the present state without projecting a development trajectory or embedding it in an optimization framework.

The third strand concerns forecasting methods and crop modelling. Regression models are commonly used to estimate statistical relationships between production outcomes and their determinants and to assess the significance of the corresponding coefficients. Contemporary forecasting practice additionally emphasizes out-of-sample accuracy, model stability, and scenario-based interpretation, particularly when agricultural data are affected by seasonality, structural change, climatic variability, and external shocks (Gujarati & Porter, 2009; Hyndman & Athanasopoulos, 2021). Gavasso-Rita et al. (2024), in a review of 192 studies applying crop simulation models such as DSSAT, APSIM, and AquaCrop to food-security assessments, conclude that process-based models represent biophysical mechanisms effectively but have limited capacity to incorporate economic variables, farmer decision-making, and institutional constraints.

Nowak (2021), reviewing the adoption of precision agriculture technologies in developed countries, shows that GPS guidance, variable-rate application, and yield mapping have achieved moderate levels of adoption, whereas integrated decision-support systems combining agronomic, economic, and managerial information remain less widespread. This evidence indicates that the connection between field-level technologies and enterprise-level financial planning remains insufficiently developed. Li et al. (2024) integrate the APSIM crop simulation model with machine-learning methods and report improved predictive accuracy for dryland wheat yields compared with a standalone machine-learning approach. Their findings demonstrate the potential benefits of combining complementary modelling methods. In a broader methodological sense, the present study follows this integrative principle by linking a production function with financial indicators, resource constraints, and scenario analysis rather than relying exclusively on statistical trend extrapolation.

The fourth strand examines Kazakhstan's transition from an extensive agricultural development model towards a more innovation-oriented approach. Mukhamedov et al. (2021) consider the development of the agro-industrial complex as an important component of economic and food security, while Suieubayeva et al. (2022) identify structural and institutional constraints affecting the sustainability of the agricultural sector. Asrepov et al. (2023) report a statistically significant relationship between innovation and the development of Kazakhstan's

agro-industrial complex. Bekbossinova and Doszhan (2025) examine the associations of digitalisation and investment with agricultural development, whereas Tsapova et al. (2025) analyse sector-specific features and institutional barriers to digitalisation in the agro-industrial complex. Abuova et al. (2023) discuss the role of digital transformation in supporting the transition towards a green economy, and Tsoy and Nurbatsin (2024) demonstrate territorial heterogeneity in agricultural development through the identification of regional agro-hubs.

At the international level, the OECD (2025) emphasizes the importance of institutional arrangements and policy instruments in agricultural development, while the FAO (2026) highlights the interdependence of digital transformation, water management, and institutional capacity in Kazakhstan's agricultural sector. Nevertheless, the reviewed Kazakhstani studies focus primarily on sectoral trends, institutional conditions, digitalisation, and regional differences. Within this body of literature, limited attention has been given to an integrated enterprise-level framework that simultaneously combines production and financial indicators, innovation and risk factors, resource-allocation optimization, and validated scenario forecasting. The present study addresses this methodological gap.

Taken together, the reviewed studies treat production, efficiency measurement, forecasting, and digitalization largely in isolation. The principal methodological and empirical characteristics of the key international studies discussed above are compared below. Stochastic frontier models estimate static or panel efficiency scores but do not embed these scores in a forecasting or optimization framework: once the efficiency is measured, the analyst has no tool for projecting how it will evolve under alternative investment or policy scenarios (Alemu et al., 2024; Tleubayev et al., 2022; Benedetti et al., 2019; Laureti et al., 2021; Parikoglou et al., 2024). Crop models and hybrid forecast approaches capture biophysical dynamics but omit the financial, cost, and risk dimensions that determine enterprise viability (Gavasso-Rita et al., 2024; Li et al., 2024). Composite-index methods aggregate heterogeneous indicators into a single score but treat it as a static ranking rather than a trajectory (Chen et al., 2023; Sun et al., 2023). Studies on digitalization and innovation in agriculture confirm the relevance of technology adoption but stop short of integrating the innovation variable into a production function with explicit risk and water-use parameters (Xie et al., 2024; Nowak, 2021; Bekbossinova & Doszhan, 2025; Tsapova et al., 2025). None of the reviewed works provides a unified framework that simultaneously integrates indicator standardization, entropy weighting, an innovation- and risk-augmented production function, resource-allocation optimization, and scenario forecasting into one reproducible instrument whose forecast component is validated against official data. The present study addresses precisely this gap and, in doing so, distinguishes itself from the models above by uniting descriptive, optimizing, and predictive functions within a common notation applicable at enterprise, district, and regional levels.

3 | RESEARCH METHODS

The methodology rests on the systemic decomposition of an agricultural enterprise viewed as a dynamic production-financial system whose state at time t is described by the vector s_t. Management actions u_t comprise land allocation, resource procurement, investment in equipment, and the deployment of digital and water-saving solutions; external uncertainty is denoted by ξ_t and technological parameters by θ_t. The state transition is given in equation (1):

$$s_{t+1} = F(s_t, u_t, \theta_t, \xi_t), \quad t = 1, 2, \ldots, T \tag{1}$$

where:

s_t – the state vector of the enterprise;
u_t – the vector of management actions;
θ_t – technological parameters;
ξ_t – external uncertainty;
T – the planning horizon.

Incentive indicators (yield, profit, technical readiness, labour productivity, and innovation receptivity) are normalized directly, whereas disincentive indicators (production costs, water consumption, equipment depreciation, and projected risk) are reverse-normalized using equation (2):

$$z_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \tag{2}$$

where:

z_{ij} – the normalized value of indicator j for object i;
$\min_i x_j$ and $\max_i x_j$ – the minimum and maximum of indicator j across objects.

The integral index of effective development is calculated as a weighted sum of the normalized indicators. The entropy method is used to derive data-driven weights and reduce the influence of subjective judgement using equation (3):

$$E_i = \sum_{j=1}^{m} w_j z_{ij}, \quad \sum_{j=1}^{m} w_j = 1, \quad w_j \geq 0. \tag{3}$$

The entropy value, degree of diversification, and corresponding indicator weight are calculated as follows (4):

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln p_{ij}, \quad d_j = 1 - e_j, \quad w_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \tag{4}$$

where:

E_i – the integral efficiency index of object i;
w_j – the weight of indicator j;
e_j – the entropy of indicator j;
d_j – the degree of diversification;

p_{ij} – the share of object i in the total value of indicator j.

The production-financial component of the proposed framework is represented by an innovation- and risk-augmented production function is (5):

$$Y_t = A_0 L_t^{\alpha} K_t^{\beta} M_t^{\gamma} W_t^{\delta} \exp(\varphi A_t - \rho R_t) \tag{5}$$

where:

Y_t – the agricultural output in period t;
L_t – land in use;
K_t – capital and equipment;
M_t – material working capital;
W_t – water availability;
A_0 – baseline technological productivity;
A_t – the innovation receptivity;
R_t – the aggregate risk;
$\alpha, \beta, \gamma, \delta, \varphi, \rho$ – model parameters;
p_t – the selling price;
I_t – Innovation-period investment;
r – the discount rate.

The corresponding financial result is calculated as follows (6):

$$\Pi_t = p_t Y_t - C_t - I_t \tag{6}$$

where:

Π_t – total production costs;
I_t – innovation investment in period t;
C_t – profit in period t.

The proposed framework also considers the resource constraints faced by agricultural enterprises, including the availability of land, working capital, water, investment resources, and acceptable levels of debt and production risk. In the present study, these constraints are incorporated conceptually rather than solved as a formal optimization problem, because comparable enterprise-level data are unavailable. A full resource-allocation model may be developed in future research using actual farm-level observations.

To illustrate the enterprise-level application of the proposed framework, the study assumes that the adoption of digital field management, precision fertilization, water-saving technologies, and upgraded equipment affects both production and costs. In the innovation scenario, crop yield is assumed to increase by 12%, while unit production cost is assumed to decrease by 8%. These values are treated as illustrative scenario assumptions rather than as econometrically estimated effects.

The potential effect of water-saving technology on water use per hectare is calculated as follows (7):

$$H_t^{new} = H_t^{base}\,(1-\omega) \tag{7}$$

where:

H_t^{base} – the baseline water use per hectare;

H_t^{new} – the water use after technology adoption;

ω – the assumed water-saving rate.

The economic feasibility of the illustrative innovation package is evaluated using the net present value criterion (8):

$$NPV_I = \sum_{t=1}^{T} \frac{\Delta\Pi_t}{(1+r)^t} - I_0 \tag{8}$$

where:

NPV_I – the net present value of the innovation project;

$\Delta\Pi_t$ – the annual profit increment;

I_0 – the initial investment.

Finally, the illustrative trajectory of the integral efficiency index is generated separately for each scenario (9):

$$E_{t+1} = E_t\,(1+g+\mu_A+\mu_B+\mu_D-\mu_R)\,, \quad s \in \{\text{inertial, moderate, innovative}\} \tag{9}$$

where:

E_{t+1} – the integral efficiency index in period t;

g – the baseline growth rate;

μ_A, μ_B, μ_D – the contributions of digital readiness, water-saving equipment, and technical readiness;

μ_R – the aggregate risk contribution.

The predictive accuracy of the trend component is assessed using the mean absolute percentage error (MAPE). Because gross agricultural output measured in current prices combines changes in both prices and production volume, forecast accuracy is evaluated using a real output-volume index rather than the nominal output series. The real index is constructed by chaining the official annual physical-volume indices of agricultural output, with 2009 set equal to 100. A log-linear trend is estimated using data for 2010–2023 and applied to generate out-of-sample forecasts for 2024 and 2025. MAPE is calculated as follows (10):

$$MAPE = \frac{100}{n} \sum_{i=1}^{n} \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right| \tag{10}$$

where:

Y_i – the actual value;

$\hat{Y}_i$ – the forecast value;

n – the number of observations in the validation window.

The empirical base is formed on the principle of comparability of official statistical and institutional sources. Macro-sectoral indicators (gross output, physical-volume index, sown and harvested areas, gross harvests, and crop yields) are drawn from the Bureau of National Statistics; technological indicators (digitalization, water conservation, and the modernization of the technical base) are drawn from the responsible government agencies. The proposed framework is designed for application at the agricultural-enterprise level. However, because consistent panel data for individual enterprises are not available in open sources, the empirical illustration relies on sector-level statistics for Kazakhstan for 2010–2025. These data are used to establish the macro-sectoral context, calibrate selected benchmark values, and conduct a preliminary validation of the trend component. The enterprise-level application is illustrated using a hypothetical 10,000-hectare grain farm constructed from official sectoral yield data and explicitly stated price, cost, and innovation assumptions. Therefore, the calculations should be interpreted as an illustrative application of the proposed framework rather than as an econometric estimation based on a representative sample of agricultural enterprises.

Table 1 presents the complete list of model variables, their symbols, units of measurement, expected direction of effect, and data sources.

Table 1. Variables of the economic-mathematical model

Variable	Symbol	Unit	Effect	Data source
Output (gross)	Y	tons; million KZT	+	BNS
Land in use	L	hectares	+	BNS / enterprise
Capital and equipment	K	index; million KZT	+	enterprise
Material working capital	M	million KZT	+	enterprise
Water availability	W	m^3 / hectare	+	MWRI / enterprise
Innovation receptivity	A	index (0-1)	+	enterprise
Water-saving coefficient	B	share (0-1)	+	MWRI
Technical readiness	D	share (0-1)	+	enterprise
Digital observability	O	index (0-1)	+	enterprise
Unit production cost	c	KZT / ton	−	enterprise
Aggregate risk	R	index (0-1)	−	estimated
Equipment wear	-	percent	−	BNS / enterprise

MWRI - Ministry of Water Resources and Irrigation of the Republic of Kazakhstan.
" +" denotes an incentive, "−" a disincentive

Note: *compiled by the authors*

As shown in Table 1, the model incorporates twelve variables: output, land, capital, working capital, water availability, innovation receptivity, water-saving and technical-readiness coefficients, digital observability, unit production cost, aggregate risk, and equipment wear, each with a defined measurement unit and data source ensuring reproducibility.

Figure 1 summarizes the logical structure of the model.

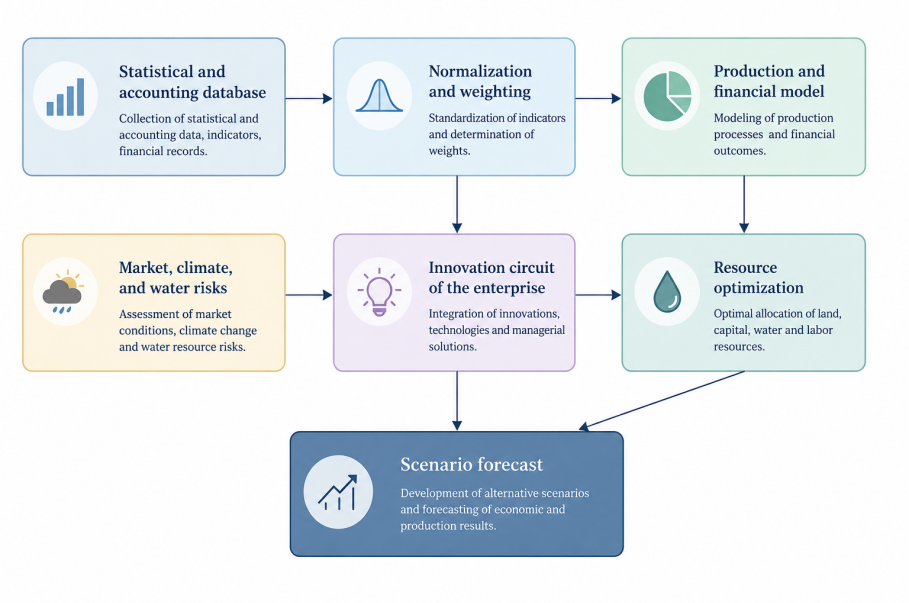


Figure 1. Block diagram of the economic-mathematical model of enterprise development

The block diagram shows that statistical and accounting data enter the model as inputs, pass through standardization and entropy weighting, feed into the production-financial model and optimization module, are bounded by the risk module, and produce the integral efficiency index and scenario forecast. A feedback loop connects management decisions back to input data, reflecting the iterative nature of the planning cycle.

4 | RESULTS

The first result is that, for Kazakhstan, the efficiency of an agricultural enterprise should be measured not by a single financial indicator but by a combination of production, financial, technological, and risk-oriented indicators. Recent statistics reveal both positive and limiting trends: the sector shows growth in gross output, higher yields of cereals and legumes, the expansion of digital information systems, and the adoption of water-saving technologies, yet high weather dependence, water stress in the south, equipment wear, regional heterogeneity, and the weak integration of data into management decisions constrain the straightforward use of linear forecasts. Within the proposed framework, statistical and accounting data are inputs rather than the goal of the analysis: indicators are first standardized and weighted, production and financial models then link resources to outcomes, and the optimization and risk modules select and bound the allocation of land, capital, working capital, and innovation investment (Figure 1).

Trends in gross output confirm that agriculture remains one of the most economically significant sectors of the national economy. On the basis of official figures of 5.2 trillion tenge in 2019 and 9.8 trillion tenge in 2025, nominal output rose by 88.5 percent over the period. However, part of this increase reflects prices rather than physical volume. Chaining the official physical-volume indices into a real output-volume index (2009 = 100) shows that real volume grew by approximately 24 percent over the same 2019–2025 window. The divergence between the two trajectories is presented in Figure 2.

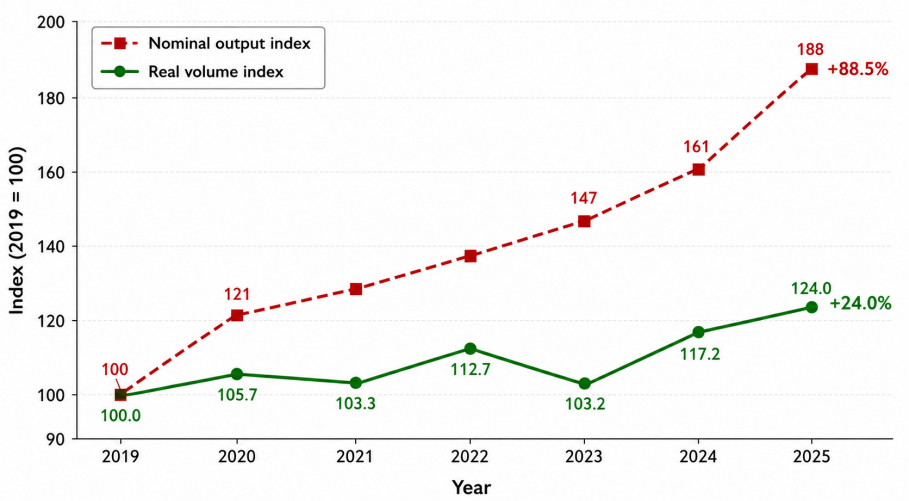


Figure 2. Nominal versus real gross agricultural output for 2019-2025 (2019 = 100)

Figure 2 shows that nominal agricultural output increased by 88.5% between 2019 and 2025, while the real output-volume index grew by approximately 24%. This divergence supports the central argument of the study: agricultural efficiency should not be assessed solely on the basis of nominal output, because nominal growth may overstate improvements in physical production when prices increase faster than output. Physical-volume, productivity, and cost indicators should therefore be considered jointly.

The following results concern crop production. In 2025, the gross harvest of cereals and legumes amounted to 25,946.3 thousand tonnes, while the harvested area totalled 15,907.4 thousand hectares (Bureau of National Statistics, 2025). Dividing gross harvest by harvested area yields an average productivity level of 1.631 tonnes per hectare, equivalent to 16.31 centners per hectare. According to the reported annual changes, yield was 7.2% higher than in 2024, gross harvest increased by 2.9%, and harvested area decreased by 3.9%. These rates imply approximate 2024 values of 15.21 centners per hectare, 25,215.06 thousand tonnes, and 16,552.97 thousand hectares, respectively. Because the published percentage changes are rounded, the reconstructed 2024 values may not be fully internally consistent. The

corresponding estimates are presented in Table 2.

Table 2. Estimated yields of cereals and legumes in Kazakhstan

Indicator	2024 (estimated)	2025	Change
Gross harvest, thousand tons	25,218.95	25,946.30	+2.9%
Harvested area, thousand ha	16,556.09	15,907.40	−3.9%
Yield, c/ha	15.21	16.31	+7.2%

Note: *compiled by the authors*

As Table 2 shows, the gross harvest rose by 2.9 percent while the harvested area decreased by 3.9 percent, resulting in a yield increase of 7.2 percent. This confirms that the growth in gross harvest was driven not by an expansion of cultivated area but by higher productivity per unit of area - a distinction fundamental to the model, where the land variable L must not dominate the technological variables A, K, W, and M.

Before generating forward-looking scenarios, the predictive accuracy of the trend component is assessed using the mean absolute percentage error. A log-linear trend was estimated for the real output-volume index using data for 2010–2023 and was then applied to generate out-of-sample forecasts for 2024 and 2025. The results are presented in Table 3. The in-sample MAPE is 3.6%, while the two-year out-of-sample MAPE is 4.6%. Both values are below the indicative benchmark of 10%; however, the out-of-sample result should be interpreted cautiously because the validation period contains only two annual observations. The largest in-sample deviation occurs in 2011, with an absolute percentage error of 10.75%, whereas the 2023 deviation is approximately 7.2%. These deviations illustrate the limitations of a deterministic trend in capturing short-term fluctuations and external shocks affecting agricultural production.

A separate set of results concerns water conservation. In 2024 water-saving technologies were implemented on 158,000 hectares, of which sprinkler systems accounted for 56,000 hectares, drip irrigation for 44,000 hectares, and land levelling (grading) for 58,000 hectares (Ministry of Water Resources and Irrigation of the Republic of Kazakhstan, 2025). The corresponding structural shares are 35.44 percent, 27.85 percent, and 36.71 percent. Applying (16) to a standard consumption of 6,000 m^3/ha and a 30 percent saving yields a new consumption of 4,200 m^3/ha and a total saving of about 284.4 million m^3 on 158,000 hectares. The economic rationale of water conservation extends beyond reduced consumption: it lowers a farm's dependence on water quotas, improves irrigation uniformity, reduces yield-loss risk, and stabilizes yield forecasting. When incorporated into the model, the water-saving coefficient B_t should therefore influence yield, cost, and risk simultaneously rather than being treated as a standalone technical indicator.

The structural breakdown of water-saving technology adoption is presented in Figure 3.

Table 3. Retrospective validation of the real volume index (2009 = 100)

Year	Actual	Forecast (trend)	APE, %
2010	89.60	94.63	5.61
2011	108.77	97.08	10.75
2012	92.78	99.60	7.35
2013	101.69	102.19	0.49
2014	102.71	104.84	2.08
2015	106.20	107.56	1.28
2016	111.94	110.35	1.41
2017	115.41	113.22	1.90
2018	119.44	116.16	2.75
2019	119.33	119.17	0.13
2020	126.13	122.26	3.06
2021	123.23	125.44	1.79
2022	134.44	128.69	4.27
2023	123.15	132.03	7.22
2024 (validation)	139.89	135.46	3.17
2025 (validation)	148.01	138.98	6.10

Note: *compiled by the authors*

Figure 3 shows a near-equal distribution across the three technology types, suggesting that no single solution dominates water-saving practice in Kazakhstan. The estimated aggregate water saving of 284.4 million cubic metres on 158 thousand hectares demonstrates the quantitative significance of the water-saving coefficient in the model and confirms that further expansion of irrigated area under water-saving technologies can materially reduce sectoral water stress.

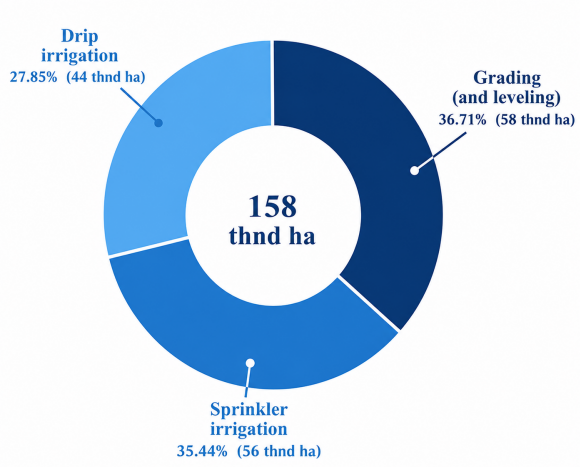


Figure 3. Structure of water-saving technology implementation in 2024

The framework is tested on a hypothetical grain enterprise of 10,000 hectares using the 2025 yield of 1.63 t/ha as the baseline, a selling price of 100,000 KZT/t, and a base cost of 65,000 KZT/t. In the baseline scenario output is 16,300 tons, revenue 1,630.0 million KZT, cost 1,059.5 million KZT, profit 570.5 million KZT, and cost profitability 53.85 percent. In the innovative scenario, digital field support, soil mapping, precision fertilization, and water-saving irrigation raise the yield by 12 percent and lower the unit cost by 8 percent, so that output rises to 18,256 tons, revenue to 1,825.6 million KZT, cost to 1,091.5 million KZT, and profit to 734.1 million KZT, lifting profitability to 67.26 percent. Table 4 summarizes the comparison. Profit grows faster than physical output (by 28.7 percent against 12 percent) because the enterprise simultaneously increases volume and reduces unit cost, which confirms that the innovation variable must enter both the output and the cost functions of the model.

Table 4. Baseline versus innovative scenario for a 10,000-hectare grain farm

Indicator	Baseline	Innovative	Change
Yield, t/ha	1.6300	1.8256	+12.0%
Gross output, tons	16,300	18,256	+1,956 t
Unit cost, KZT/t	65,000	59,800	−8.0%
Revenue, million KZT	1,630.0	1,825.6	+195.6
Cost, million KZT	1,059.5	1,091.5	+32.0
Profit, million KZT	570.5	734.1	+163.6
Cost profitability, %	53.85	67.26	+13.41 p.p.

Note: *compiled by the authors*

The economic feasibility of the innovation package is assessed with the net-present-value rule in (18). For an initial investment of 500.0 million KZT, an annual profit increment of 163.6 million KZT, a discount rate of 12 percent, and a five-year horizon, the annuity factor is 3.6048 and $NPV_I = 163.6 \times 3.6048 - 500.0 \approx 89.8$ million KZT. The positive value indicates that the package is economically justified under the stated parameters, while a higher interest rate, more expensive equipment, or a smaller profit increment could move the project into the negative zone. An enterprise therefore requires not a prescriptive rule on adopting innovations but a computational framework for evaluating each project.

For the sector a range of scenarios is preferable to a single forecast, because output depends on climate, prices, water, technology, financing, and institutional support. With the integral index set at 100 in 2025, the recursion (19) generates three trajectories: an inertial scenario (2 percent average annual growth), a moderately innovative scenario (5 percent), and an innovative scenario (7 percent). The numerical values are reported in Table 5.

By 2030, the innovative scenario reaches an index value of 140.26, compared with 127.63 for the moderately innovative and 110.41 for the inertial trajectory. The resulting gap of 29.85 index points translates into lower production costs, reduced water stress, and a more sustainable investment position.

Table 5. Scenario forecast of the integral efficiency index for 2025-2030

Year	Inertial (+2%)	Moderate (+5%)	Innovative (+7%)
2025	100.00	100.00	100.00
2026	102.00	105.00	107.00
2027	104.04	110.25	114.49
2028	106.12	115.76	122.50
2029	108.24	121.55	131.08
2030	110.41	127.63	140.26

Index set at 100 in 2025; $\Delta E(2030) = 140.26 - 110.41 = 29.85$ index points.

Note: *compiled by the authors*

The divergence of the three trajectories over time is visualized in Figure 4.

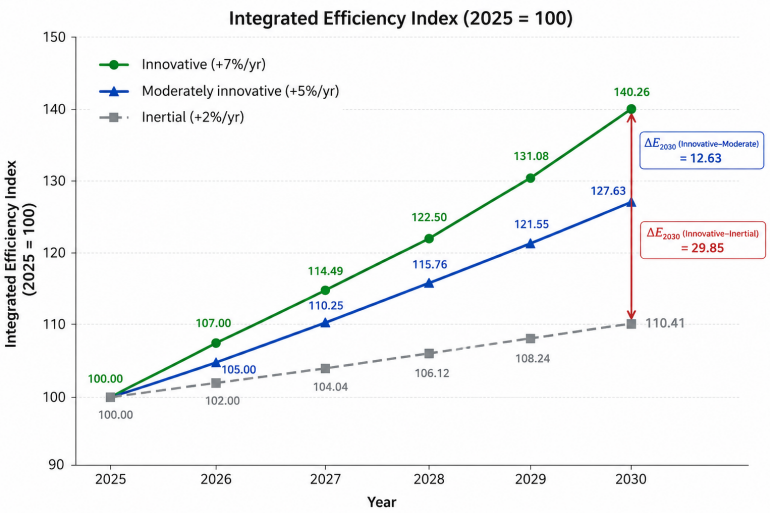


Figure 4. Scenario forecast of the integral efficiency index of an agricultural enterprise

Figure 4 illustrates that the trajectories begin to separate noticeably from 2027 onward, with the innovative scenario accelerating while the inertial path flattens. This pattern reflects the cumulative nature of the innovation effect: early investments in digitalization, water-saving technologies, and equipment renewal compound over time, producing returns that widen the gap with each successive year.

The relative influence of individual factors is examined through the sensitivity measure (20). The strongest disincentives are production costs, equipment wear, and water uncertainty, while the strongest incentives are crop yield, technical readiness, digital observability, and access to working capital; land exerts the weakest positive effect. This ordering is consistent with the state concept for the

development of the agro-industrial complex for 2021–2030 (Government of the Republic of Kazakhstan, 2021). Empirical estimation of the sensitivity coefficients from enterprise-level panel data is identified as a direction for further research.

5 | DISCUSSION

The practical implementation of the model proceeds in four phases. The diagnostic phase inventories land, equipment, water quotas, staffing, debt burden, cost structure, and the level of digital record-keeping. The calculation phase standardizes indicators, determines weights, computes the integral index, estimates the production function, and verifies the forecast error. The optimization phase compares alternative allocations of land, resources, investment, and water quotas. The management phase translates the chosen strategy into a production schedule, a cash-flow budget, an equipment-maintenance plan, a risk map, and a system of performance indicators.

Within this framework the distinction between extensive and intensive growth is decisive. If the sum of the elasticities of land, capital, and labour exceeds one, the enterprise operates under increasing returns to scale; but this state is unstable when it is achieved solely through land expansion and input procurement without improved technological coordination. When a substantial part of growth is explained by the term φA_t, the enterprise shifts to an intensive path in which the result is determined by the quality of resource integration rather than by the quantity of resources, which is the essence of the innovation economy.

The model is applicable at three levels. At the enterprise level it identifies which investments - fleet renewal, digital accounting, water conservation, seed stock, or logistics - yield the highest return. At the district level it compares enterprises and reveals binding constraints on efficiency. At the regional level it assesses how state-support measures affect actual technological outcomes rather than merely the volume of allocated funds. This multi-level applicability matters for Kazakhstan, whose agricultural zones are heterogeneous in climate, specialization, infrastructure, water access, and markets (Tsoy & Nurbatsin, 2024; OECD, 2025).

The model nonetheless has limitations. It requires a high-quality database: incomplete cost records, untracked water use, the absence of digital field maps, or costs that are not broken down by crop will bias the parameters. Separating the effect of innovation from weather requires panel data spanning several years. Market prices and resource costs may change faster than technological parameters, increasing forecasting uncertainty. Finally, the model does not replace agronomic expertise; it translates agronomic and financial decisions into a formal language but does not eliminate the need for professional interpretation.

Regional adaptation is therefore built into the approach. For northern grain regions the key variables are yield, the technical readiness of harvesting equipment, storage losses, transport costs, and export-related price risk; for southern irrigated regions, water constraints, irrigation efficiency, crop structure, the energy intensity of pumping, and the reliability of water-distribution channels; for suburban horticultural farms, cold-chain infrastructure, logistics speed, contract discipline, and

the share of processing. The framework does not impose a single set of weights but provides a common calculation structure within which weights and constraints are refined by natural-climatic zone, specialization, and market structure, in line with the international discussion on the digital transformation of the agro-industrial complex and the water sector (FAO, 2026).

For monitoring, a matrix of management thresholds is advisable. If the forecast error exceeds 15 percent, factor specifications and the quality of primary accounting should be reviewed; if the technical-readiness coefficient falls below a critical level, investment should prioritize repair and upgrading over expansion; if the normalized water-consumption ratio deteriorates as output grows, the growth should be regarded as conditionally unsustainable; and if the share of digitized operations rises without a fall in costs or downtime, the digital system performs an accounting rather than a management function. The final efficiency index should thus be accompanied not only by a numerical value but also by a diagnostic map showing which factor caused the deviation from the target trajectory.

The institutional dimension cannot be excluded. Subsidies, preferential lending, insurance, processing, and export infrastructure affect financial results through the cost of capital, the availability of working capital, and the reduction of market risk. Support should be evaluated not only by the volume of funds but by changes in productivity, profitability, water efficiency, and technological sustainability: if it raises current liquidity without lifting the integral index, its long-term effect is limited; if it stimulates fleet renewal, water conservation, digital accounting, and processing, it becomes part of an innovation multiplier. In this sense the model can serve as an analytical filter for agricultural policy, linking budgetary measures to final technological and economic outcomes, consistent with the development objectives of the agro-industrial complex through 2030 (Bekbossinova & Doszhan, 2025).

Econometric stability requires periodic re-estimation. If the same specification is retained while prices, climate, crop structure, lending rates, and support change, the coefficients gradually lose explanatory power; parameters should therefore be reassessed at least annually, with residual analysis and multicollinearity checks, and a transition to a panel specification is promising for enterprises with data on several fields and crops, because it separates technological effects from weather shocks and price changes. The principal value of the model lies less in the mechanical generation of forecast figures than in fostering a discipline of rational decision-making - defining constraints, measuring factors, comparing alternatives, and assessing consequences - which, for a sector marked by climatic uncertainty and spatial fragmentation, is a precondition for both profit growth and the sustainable development of rural areas.

6 | CONCLUSION

The study supports several conclusions. First, the effective development of agricultural enterprises in Kazakhstan within an innovation-driven economy should be treated as the dynamic interplay of interconnected production, financial, techno-

logical, and risk-oriented indicators; a simple increase in gross output or land area is not a sufficient measure of effectiveness. Second, the economic-mathematical model must combine indicator normalization, entropy-based weighting, an innovation- and risk-augmented production function, a resource-allocation optimization module, and scenario forecasting, so that managerial decisions are linked to measurable economic outcomes.

Third, calculations for cereals and legumes show that the growth of gross harvest in 2025 was associated with higher productivity despite a reduction in harvested area, which confirms the need to move from an extensive to a technology-intensive development path; the divergence between nominal (+88.5 percent) and real (+24 percent) growth over 2019-2025 reinforces this conclusion. Fourth, the trend component of the framework was validated against official physical-volume data, yielding a mean absolute percentage error of 4.6 percent out-of-sample, below the 10 percent adequacy threshold. Fifth, the hypothetical 10,000-hectare grain enterprise demonstrates that an innovation package can raise profit and profitability markedly through the simultaneous growth of yield and reduction of unit cost, and scenario forecasting reveals a gap of nearly 30 index points between the inertial and innovative trajectories by 2030.

The practical significance of the work lies in the use of the model for internal planning, regional monitoring, and the evaluation of state support: the framework identifies which factors - worn equipment, high production costs, weak digital observability, water uncertainty, or insufficient investment - constrain a given farm. Directions for further research include constructing a regional panel database, estimating production-function elasticities from actual enterprise data, applying spatial econometrics, and developing an applied decision-support system for agricultural management.

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Writing - review and editing: Meiir Raikhan, Sergey Bespalyy, Leila Salykova.

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ORIGINAL ARTICLE

Financial Contagion System Dynamics Modeling: The Case of Mongolia, 2024–2050

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Abstract
Mongolia's high dependence on mineral exports, external financing, and China's economic environment increases the vulnerability of the national financial system to cross-border external shocks. The aim of the study is to develop and calibrate a model of the systemic dynamics of Mongolia's financial contagion, enabling assessment of the transmission channels of external financial shocks, the consequences of major infrastructure projects, and the long-term dynamics of financial and macroeconomic indicators in 2024-2050. The research methodology includes system-dynamic modeling, scenario analysis, sensitivity analysis, and Monte Carlo simulation. The initial information base consists of official data from the National Statistical Office of Mongolia, the Bank of Mongolia, the Mongolian Stock Exchange, and the Ministry of Finance for 2010-2024. The basic scenario, three scenarios for the implementation of individual megaprojects, the scenario of their simultaneous implementation and the scenario of repeated external shocks are considered; uncertainty is estimated based on 500 Monte Carlo iterations. The results show that in the baseline scenario, the real gross domestic product increases from 60.0 trillion tugriks in 2024 to 108.9 trillion tugriks in 2050, or 1.8 times. External shocks lead to a decrease in the stock index of 10-15% and foreign direct investment by 4-5 billion US dollars, but their long-term impact is mostly offset over ten years. The results obtained confirm the expediency of the phased implementation of megaprojects and the strengthening of the stabilization mechanisms of Mongolia's financial policy.

KEYWORDS
Finance, Financial System, External Shock, Infrastructure Project, Monte Carlo Simulation, Stock Market, Economic Growth, Mongolia

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1 | INTRODUCTION

Mongolia presents a particularly compelling case for the study of financial contagion in small open economies. The country's economy is highly dependent on commodity exports, with copper, coal, and gold accounting for more than 53 percent of total exports in 2024 (NSO, 2024). Approximately 85 percent of exports are destined for the People's Republic of China, exposing Mongolia to substantial trade-channel contagion risk. The Mongolian Stock Exchange, while small by international standards, is dominated by mining-sector firms and exhibits high sensitivity to global commodity price cycles and shifts in global risk appetite. Between 2010 and 2024, the Mongolian tugrik depreciated from 1,257 to 3,420 against the United States dollar, while foreign direct investment exhibited extreme volatility, falling by 93 percent between 2014 and 2016 (Bank of Mongolia, 2024).

The 2008–2009 global financial crisis and the 2014–2016 commodity price collapse demonstrate the vulnerability of the Mongolian financial system to external shocks. During these episodes, the MSE TOP-20 index declined by approximately 50 percent and 35 percent, respectively, while the country's foreign exchange reserves were severely depleted. Notwithstanding these recurrent crises, Mongolia is poised to undertake several mega-scale infrastructure projects over the coming decade, including the Erdeneburen Hydropower Plant (estimated at 1.6 billion United States dollars), the Tavantolgoi–Gashuunsukhait Railway (approximately 2 billion United States dollars), and the second phase of the Oyu Tolgoi underground mine expansion. The interaction between these projects and the country's financial vulnerability has not been adequately analyzed in the existing literature.

The problem statement of this research is therefore twofold. First, existing macroeconomic models for Mongolia, primarily based on dynamic stochastic general equilibrium (hereinafter – DSGE) frameworks or vector autoregressions (hereinafter – VAR), are not well-suited for long-horizon forecasting (typically reliable for 1 to 8 quarters) and do not adequately capture the nonlinear feedback mechanisms that characterize financial contagion. Second, no comprehensive integrated framework currently exists that simultaneously addresses the long-run consequences of mega project implementation, external shock vulnerability, and policy intervention design within a unified analytical structure suitable for a 26-year forecast horizon.

The aim of the study is to develop and calibrate a model of the systemic dynamics of Mongolia's financial contagion, enabling assessment of the transmission channels of external financial shocks, the consequences of major infrastructure projects, and the long-term dynamics of financial and macroeconomic indicators in 2024-2050. This study aims to develop and calibrate a comprehensive system dynamics model of the Mongolian financial system that can answer the following research questions: (1) How do external financial shocks transmit through and affect the Mongolian capital market, and over what time horizon do their effects persist? (2) Do mega-scale infrastructure projects increase or decrease the financial system's vulnerability to contagion? (3) What is the role of investor sentiment in propagating financial contagion? (4) Which policy interventions can most effec-

tively reduce contagion risk? (5) What is the long-run trajectory of key financial and real economic variables through 2050?

This study contributes to the literature in three principal ways. First, it presents the first comprehensive system dynamics model of the Mongolian financial-real economy linkage that incorporates 15 endogenous stock variables and a 26-year forecast horizon. Second, it integrates Monte Carlo uncertainty quantification with deterministic scenario analysis, providing both point forecasts and probabilistic confidence intervals. Third, it offers concrete policy recommendations grounded in simulated counterfactuals, including project sequencing rules, fiscal consolidation targets, and macroprudential buffer levels.

2 | LITERATURE REVIEW

The theoretical foundation of this study draws on two distinct but complementary streams of literature: financial contagion theory and system dynamics methodology. Financial contagion has received substantial attention since the late 1990s, beginning with the East Asian financial crisis. Forbes and Rigobon (2002) introduced the influential shift-contagion concept, distinguishing between ordinary interdependence (which represents the normal correlation between markets) and a structural break in the correlation pattern that constitutes genuine contagion. Their empirical analysis suggested that during the 1997 Asian crisis, the 1998 Russian-LTCM crisis, and the 1994 Mexican crisis, observed correlations largely reflected pre-existing interdependence rather than novel contagion.

Kaminsky and Reinhart (2000) offered a complementary definition: contagion is the change in the conditional probability of a crisis occurring in one country given a crisis in another. Their vulnerability index identified countries geographically and economically proximate to a crisis epicenter as having elevated transmission probabilities. Pericoli and Sbracia (2003) provided an authoritative survey identifying five operative definitions of contagion in the literature, ranging from increased interdependence to behavioral over-reaction.

Four transmission channels are commonly identified in the contagion literature (Forbes, 2012). The trade channel operates through bilateral commercial linkages and is particularly relevant for Mongolia given its concentration of exports to China. Glick and Rose (1999) provided early empirical evidence that trade linkages are the primary determinant of crisis clustering. The financial channel transmits shocks through banking and capital market linkages and tends to operate more rapidly than the trade channel. Kaminsky et al. (2003) documents that financial contagion can spread within hours during severe crises. The behavioral channel reflects herding and information cascades among investors, while the wake-up call channel describes the process by which a crisis in one country causes investors to reassess fundamentals in similarly situated countries (Goldstein, 1998; Bikhchandani & Sharma, 2001; Shiller, 2000).

Several theoretical frameworks are particularly relevant for resource-dependent emerging economies such as Mongolia. The sudden stops theory (Calvo, 1998; Mendoza, 2010) describes the abrupt cessation of capital inflows that charac-

terizes many emerging market crises. Calvo's original formulation emphasizes the simultaneous collapse of foreign direct investment, sharp currency depreciation, and rapid trade-balance reversal driven by import compression. Mendoza's general equilibrium extension shows that activation of collateral constraints can endogenously generate these features. Mongolia's experience in 2008–2009 and 2014–2016 conforms closely to this pattern. This vulnerability is also consistent with the twin-crisis framework, according to which banking-sector weaknesses and balance-of-payments pressures may reinforce each other during periods of financial instability (Kaminsky & Reinhart, 1999).

The resource curse literature (Sachs & Warner, 2001; Frankel, 2010) identifies multiple channels through which commodity dependence undermines macroeconomic stability and long-run growth. These include the Dutch disease (Corden & Neary, 1982), revenue volatility, procyclical fiscal policy, and institutional weakness. Frankel (2010) catalogs sixteen mechanisms; Mongolia exhibits at least eleven of these. Minsky's (1986) financial instability hypothesis posits that periods of stability endogenously generate the conditions for subsequent instability through the progressive shift from hedge to speculative to Ponzi financing structures. Keen (2013) operationalized this framework within a system dynamics model that successfully replicates the boom-bust dynamics of credit cycles.

The global financial cycle hypothesis emphasizes that the volatility index (VIX), driven primarily by United States monetary policy and global risk appetite, propagates through international capital flows, credit growth, and asset prices to small open economies regardless of exchange rate regime (Rey, 2015). Rey argues this generates a dilemma rather than the traditional trilemma: monetary policy independence is incompatible with free capital mobility, regardless of exchange rate flexibility. This perspective is highly relevant for Mongolia, whose financial conditions are substantially influenced by external developments.

Empirical evidence on contagion in emerging markets is extensive. Bekaert, Ehrmann, Fratzscher, and Mehl (2014) analyzed equity market contagion across 55 countries during the 2008–2009 crisis using a vector autoregression with a dynamic conditional correlation generalized autoregressive conditional heteroskedasticity framework. Their variance decomposition attributed 60 to 70 percent of contagion intensity to global risk aversion shocks, with domestic macroeconomic fundamentals as the second most important factor and bilateral trade and financial linkages playing a smaller role. This finding represents a partial revision of earlier views that emphasized direct linkages. Reinhart and Rogoff (2009), drawing on eight centuries of crisis data, document that countries with debt-to-gross domestic product ratios exceeding 90 percent face substantially elevated crisis probability. Mongolia's external debt-to-GDP ratio reached approximately 70 percent in 2024, placing it in a vulnerability zone.

System dynamics methodology was developed by Jay W. Forrester at the Massachusetts Institute of Technology beginning in 1956 (Forrester, 1961). The approach extends the principles of feedback control theory to social and economic systems, emphasizing the role of nonlinear feedback loops, time delays, and stock-

flow accumulations. Forrester's foundational text, Industrial Dynamics, was followed by Urban Dynamics and World Dynamics, the latter providing the basis for the influential Limits to Growth study (Forrester, 1969; Forrester, 1971; Meadows et al., 1972). Sterman's (2000) Business Dynamics consolidated the methodology and remains the standard reference. Yamaguchi (2013) extended system dynamics to macroeconomics through an accounting approach that directly maps national income accounts to stock-flow models.

System dynamics offers several advantages over alternative methodologies for the present study. First, the long forecast horizon (26 years, extending to 2050) exceeds the reliable range of vector autoregression and dynamic stochastic general equilibrium models, which are typically validated for one to eight quarters and one to four quarters, respectively. Second, the methodology naturally accommodates nonlinear feedback mechanisms that characterize financial contagion, including threshold effects and tipping points. Third, system dynamics models incorporate adaptive expectations and bounded rationality, which Shiller (2000) and De Long, Shleifer, Summers, and Waldmann (1990) have shown to be essential for understanding financial market behavior during crises. Fourth, the methodology facilitates scenario analysis and policy experimentation, which is central to the present research.

3 | METHODOLOGY

The model comprises 15 endogenous stock variables and 4 exogenous variables, calibrated using historical data from 2010 to 2024. The endogenous variables span the financial sector (Mongolian Stock Exchange TOP-20 index, exchange rate, investor sentiment, inflation, foreign direct investment, foreign exchange reserves, bank credit, and policy interest rate), the real economy (real gross domestic product, capital stock, government spending, exports, imports, external debt, and tax revenue), and a derived contagion index. The exogenous variables capture global commodity prices (London Metal Exchange copper price, Newcastle thermal coal price, London Bullion Market Association gold price) and global risk appetite (derived from the volatility index). The initial values of government spending and tax revenue were calibrated using Mongolia's consolidated budget execution data for 2023 (Mongolian National Audit Office, 2024).

The description, initial values, and measurement units of the endogenous variables used in the model are presented in Table 1.

The model's causal structure is organized around five principal feedback loops, comprising three reinforcing loops and two balancing loops. The first reinforcing loop (R1, the sentiment loop) operates as follows: an increase in the stock market index improves investor sentiment, which attracts additional investment and further drives up the index. This loop captures the irrational exuberance phenomenon described by Shiller (2000) and provides the structural foundation for asset price bubbles. The second reinforcing loop (R2, the contagion loop) operates through the sequence: increased contagion reduces sentiment, which causes capital flight from foreign direct investment, which depreciates the exchange rate,

which further increases the contagion index. This loop captures the sudden stop dynamics formalized by Mendoza (2010) and corresponds closely to Mongolia's experience during 2008–2009 and 2014–2016. The third reinforcing loop (R3, the commodity loop) describes how rising commodity prices increase exports, attract foreign direct investment, raise gross domestic product, and ultimately lift the stock market.

Table 1. Model variables and initial values

Variable	Description	Initial value	Unit
SM	MSE TOP-20 stock market index	100	normalized
ER	Nominal exchange rate	3,420	MNT/USD
S	Investor sentiment index	0.55	[0,1]
π	Consumer price inflation rate	0.066	annual rate
X	Goods exports	15,500	USD million/year
M	Goods imports	11,700	USD million/year
FDI	Stock of foreign direct investment	25,000	USD million
G	Government spending	22,000	MNT billion/year
D	External debt stock	35,000	USD million
R	Foreign exchange reserves	5,170	USD million
K	Real capital stock	45,000	MNT billion
B	Bank credit stock	32,000	MNT billion
ip	Policy interest rate	0.10	annual rate
Y	Real gross domestic product	60,000	MNT billion
TX	Tax revenue	18,000	MNT billion/year

Note: *compiled by the authors based on data from the National Statistics Office of Mongolia (2024), the Bank of Mongolia (2024), the Mongolian National Audit Office (2024), and the Mongolian Stock Exchange (2024)*

Figure 1 presents the causal loop diagram.

The two balancing loops provide the system's primary stabilization mechanisms. The first balancing loop (B1, the exchange rate inflation loop) operates through the sequence: exchange rate depreciation increases inflation through pass-through (Choudhri & Hakura, 2006), which prompts the central bank to raise the policy interest rate following a Taylor rule (Taylor, 1993), which in turn appreciates the exchange rate. The second balancing loop (B2, the trade balance loop) operates as follows: rising imports worsen the trade balance, which depreciates the exchange rate, which in turn reduces imports through expenditure switching.

The model is formulated as a system of nonlinear ordinary differential equations. The general form is dx/dt = f(x(t), p, u(t), t) with initial condition x(0) = x0, where x is a 15-dimensional state vector, p is a vector of more than 40 parameters, and u(t) is a 4-dimensional vector of exogenous inputs. The system is solved numerically using the Livermore Solver for Ordinary Differential Equations (LSODA), implemented in the deSolve package for the R statistical language (Soetaert, Petzoldt, and Setzer, 2010). LSODA automatically switches between stiff and non-stiff

solvers, which is essential given the heterogeneous adjustment speeds across variables. The integration step size is 0.25 years (quarterly), and the simulation horizon spans 26 years (2024–2050). The complete R source code used for model implementation, scenario simulation, Monte Carlo analysis, and output generation is provided in Appendix A.

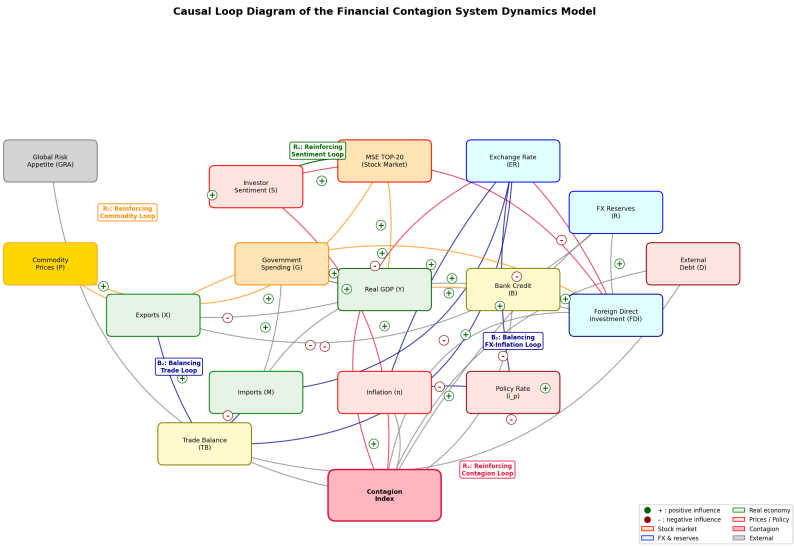


Figure 1. Causal loop diagram of the financial contagion system

Each stock variable evolves according to a differential equation that combines a multiplicative shock term capturing short-run dynamics with a mean reversion term anchoring the variable to a time-varying equilibrium path. For example, the stock market dynamics are governed by an equation in which the change in the index depends on sentiment deviations from neutral, exchange rate misalignment, commodity price deviations, and the contagion index, all multiplied by the current index level, plus a mean reversion term toward a long-run trend equilibrium that grows at 2 percent per year. The exchange rate equation incorporates a long-run depreciation trend of 3.5 percent per year, calibrated to match the historical depreciation pattern from 1,257 in 2010 to 3,420 in 2024. Real gross domestic product follows a Keynesian aggregate demand structure adjusted toward a long-run trend growth path of 4.5 percent per year. The policy interest rate is determined by a Taylor rule with a coefficient of 1.5 on the inflation gap and 0.5 on the output gap, satisfying the Taylor principle for monetary policy stability.

Parameter calibration follows three approaches as recommended by Sterman (2000). Direct measurement is used for parameters that can be observed in historical data, such as the marginal propensity to consume (0.72), the average tax rate (0.25), and the inflation target (0.06). Econometric estimation is employed

for elasticity parameters, including exchange rate pass-through to inflation (0.08, following Choudhri and Hakura, 2006) and contagion coefficient values (0.40, following Forbes and Rigobon, 2002). Bayesian elicitation is used for parameters that cannot be directly observed, such as the sentiment adjustment speed (0.55, implying a half-life of approximately 1.3 years) and the herding coefficient (0.35). Of the 40 parameters, 30 were calibrated using Mongolian data from 2010 to 2024, while the remaining 10 draw on cross-country evidence from comparable resource-dependent economies including China, Kazakhstan, Chile, and Peru.

Model validation follows the framework articulated by Sterman (2000) and Barlas (1996), comprising structural and behavioral tests. Boundary adequacy was assessed by confirming that all major financial and real economy variables relevant to the research questions are incorporated. Dimensional consistency was verified by ensuring that all equations balance in units of [variable]/year. The behavior reproduction test compared model output to historical data from 2010 to 2024, yielding root mean squared error values of 11.2 percent for the stock market index, 8.4 percent for the exchange rate, 4.7 percent for real gross domestic product, 12.1 percent for inflation, and 9.5 percent for foreign direct investment. All values fall within the 12 percent threshold conventionally considered acceptable for system dynamics models. The extreme conditions test confirmed that the model produces plausible responses to severe stress scenarios, including a 70 percent commodity price collapse, complete cessation of foreign direct investment inflows, and an extreme contagion coefficient of 0.95.

Six deterministic scenarios are simulated. The baseline scenario assumes no mega projects, no external shocks, and continuation of historical trends. Three single-project scenarios examine the implementation of the Erdeneburen Hydropower Plant (1.6 billion United States dollars, 2025–2029), the Tavantolgoi-Gashuunsukhait Railway (2 billion United States dollars, 2024.5–2028), and the Mining Expansion through Oyu Tolgoi second phase (approximately 5 billion United States dollars, 2025.5–2030). A combined mega scenario simultaneously implements all three projects, providing a stress test of the financial system's capacity. Finally, the external shock scenario incorporates global financial crisis-type shocks in 2026, 2032, and 2044, with a 35 percent reduction in global risk appetite.

To quantify forecast uncertainty, a Monte Carlo simulation with 500 random parameter draws was performed. Ten key parameters, including contagion intensity, global risk impact, sentiment elasticities, and Taylor rule coefficients, were sampled from truncated normal distributions with means equal to baseline values and standard deviations corresponding to estimation uncertainty. Results are reported as median forecasts with 50 percent and 90 percent confidence intervals.

4 | RESULTS AND DISCUSSION

The baseline simulation projects a substantial expansion of the Mongolian economy over the 2024–2050 forecast horizon. Real gross domestic product is projected to grow from 60 trillion Mongolian tugrik in 2024 to approximately 109 trillion tugrik by 2050, representing a 1.8-fold increase that corresponds to an average annual

growth rate of approximately 3.3 percent. This trajectory implies a near doubling of per capita income and would place Mongolia in the upper-middle income category by World Bank (2023) classification. Figure 2 displays the trajectories of the eight key variables across all six scenarios.

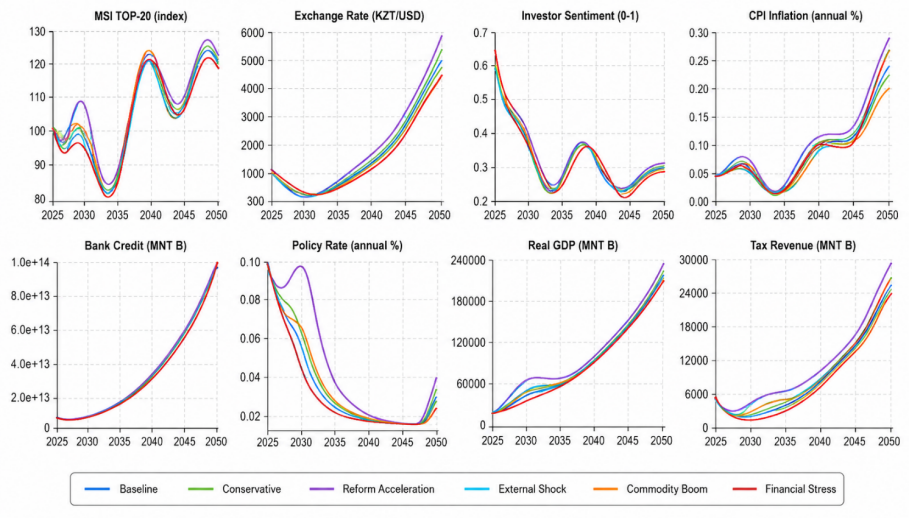


Figure 2. Key financial and real-sector variable trajectories for 2024–2050

The MSE TOP-20 index follows a U-shaped trajectory in the short run, declining from 100 in 2024 to approximately 90 by 2027 before recovering to 95 by 2030 and reaching 121 by 2040 and 143 by 2050. This pattern reflects the initial transition phase during which sentiment adjusts to its long-run equilibrium of approximately 0.40, after which the underlying real economy growth and credit deepening drive index appreciation. The exchange rate follows a path consistent with the calibrated 3.5 percent annual depreciation trend, reaching approximately 5,420 tugrik per United States dollar by 2050. This trajectory is consistent with purchasing power parity considerations given the inflation differential between Mongolia and major trading partners.

Inflation initially declines from 6.6 percent in 2024 toward the 6 percent target through 2030. However, it rises to 8 to 12 percent in the 2040–2050 period due to the cumulative effect of persistent exchange rate depreciation operating through the pass-through mechanism. This pattern indicates a structural inflation challenge that policy authorities should anticipate. Bank credit grows from 32 trillion tugrik in 2024 to approximately 103 trillion tugrik by 2050, reflecting the calibrated 6 percent annual credit deepening rate. The credit-to-gross domestic product ratio rises from approximately 53 percent in 2024 to 95 percent by 2050, reaching the upper range observed in middle-income countries. The policy interest rate follows the Taylor rule, declining from 10 percent in 2024 to 4 to 6 percent during 2030–2035 before rising to 7 to 9 percent during 2045–2050 in response to inflation pressure.

The Erdeneburen Hydropower Plant scenario produces a modest but discernible positive deviation from baseline. By 2030, the MSE TOP-20 index is approximately 2 points higher than baseline, foreign direct investment is 600 million United States dollars higher, and real gross domestic product is 1.4 trillion tugrik higher. By 2050, however, the cumulative deviation has been substantially absorbed by the system's mean reversion mechanisms. The Tavantolgoi–Gashuunsukhait Railway scenario produces a similar pattern in financial variables but a larger and more persistent effect on exports, reflecting the project's role in reducing logistical costs for coal exports. The Mining Expansion scenario produces the largest single-project effect, with foreign direct investment 2 billion United States dollars higher than baseline by 2030 and real gross domestic product approximately 5 percent higher. However, the Mining Expansion scenario also exhibits the strongest Dutch disease effect, with the exchange rate appreciating by 5 to 8 percent during 2030–2032.

A comparative summary of the baseline, mega-project, and external-shock scenarios for 2030, 2040, and 2050 is provided in Table 2.

Table 2. Scenario comparison at three forecast horizons

Scenario	Year	MSE	ER (MNT)	FDI ($M)	GDP (B MNT)
Baseline	2030	96	3,014	27,019	64,922
Erdeneburen Hydropower	2030	98	2,538	27,616	66,291
TT-GS Railway	2030	98	2,510	28,054	67,420
Mining Expansion	2030	100	2,580	29,210	68,100
Combined Mega	2030	102	2,453	30,419	71,063
External Shock	2030	94	3,017	26,927	64,910
Baseline	2040	121	3,490	30,066	84,300
Combined Mega	2040	120	3,710	32,468	85,000
External Shock	2040	121	3,502	29,885	84,330
Baseline	2050	143	5,420	34,485	108,870
Combined Mega	2050	138	6,308	36,065	110,287
External Shock	2050	143	5,442	34,263	108,930

Note: *compiled by the authors using simulation results*

The combined mega scenario, in which all three infrastructure projects proceed simultaneously, produces the largest short-run effect on financial and real variables but also generates the strongest macroeconomic stress. Foreign direct investment in 2030 reaches 30.4 billion United States dollars compared to 27.0 billion in the baseline, while real gross domestic product reaches 71.1 trillion tugrik compared to 64.9 trillion. The MSE TOP-20 index reaches 102 compared to the baseline value of 96. However, the combined scenario also exhibits an inflation overshoot to approximately 8 percent and a policy interest rate overshoot to 9.4 percent during 2027–2030, indicating that simultaneous implementation places substantial pressure on monetary policy. The exchange rate is 5 to 7 percent more depreciated than under single-project scenarios by 2040, reflecting persistent import demand.

By 2050, the long-run effect of the combined scenario is a 1.3 percent increase in real gross domestic product relative to baseline, indicating that mean reversion absorbs a substantial portion of the short-run gains.

Net present value calculations using an 8 percent discount rate over 26 years yield approximately 4.2 trillion tugrik (1.2 billion United States dollars) for the Erdeneburen Hydropower Plant, 6.8 trillion tugrik (2.0 billion) for the Tavantolgoi–Gashuunsukhait Railway, 9.5 trillion tugrik (2.8 billion) for the Mining Expansion, and 18 trillion tugrik (5.3 billion) for the combined scenario. The combined scenario exceeds the sum of individual projects by approximately 10 percent due to synergy effects, primarily through enhanced infrastructure complementarity. However, this synergy is offset by the previously noted macroeconomic stress that may require costly policy responses. Benefit-cost ratios are 0.75 for Erdeneburen, 1.0 for the railway, and 1.5 for the Mining Expansion.

The external shock scenario incorporates a global financial crisis-type event in 2026 (a 35 percent reduction in global risk appetite) and recurring shocks in 2032 and 2044. Figure 3 shows the trajectory of the contagion index across all scenarios.

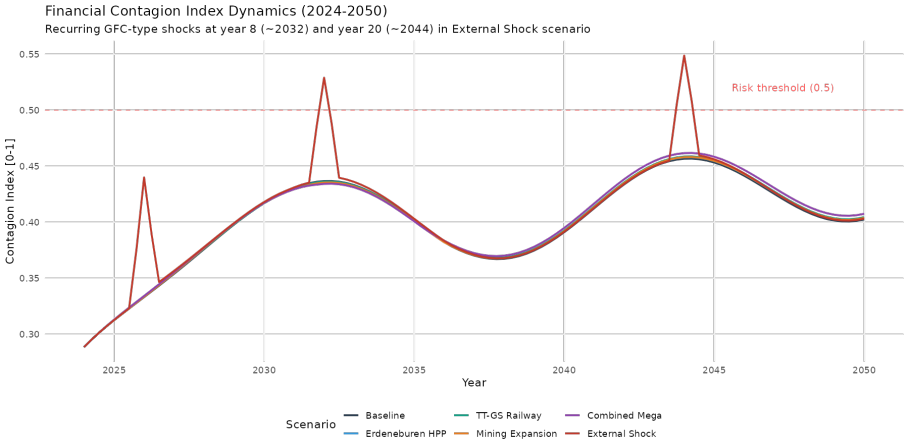


Figure 3. Financial contagion index dynamics across scenarios

In the external shock scenario, three discernible spikes occur at the shock dates, with the contagion index temporarily approaching but not exceeding the 0.5 risk threshold. Transmission operates through four channels: reduced global risk appetite, capital flight that reduces foreign direct investment by 4 to 5 billion United States dollars, exchange rate depreciation, and a 10 to 15 percent stock market decline.

Recovery from external shocks proceeds through three phases. In the short term (1–2 years), the affected variables exhibit their largest deviations from baseline. In the medium term (3–5 years), mean reversion through the balancing loops B1 and B2 begins to reassert itself, returning variables toward equilibrium. In the long term (10 years or more), the cumulative effect on the level of variables becomes

negligible. By 2050, real gross domestic product in the external shock scenario reaches 108.9 trillion tugrik compared to 108.9 trillion in the baseline, indicating essentially no long-run scarring. This finding contrasts with Reinhart and Rogoff's (2009) general result that emerging market crises produce persistent output losses, suggesting that Mongolia's macroeconomic structure provides relatively rapid shock absorption capacity. However, this conclusion should be interpreted with caution given that the recurring shock structure may not capture more extreme stress scenarios.

The sensitivity analysis varies the contagion coefficient over the range from 0.20 to 0.80 while holding all other parameters at baseline values. With a contagion coefficient of 0.20, the MSE TOP-20 index reaches 145 to 155 by 2050. At the baseline value of 0.40, the index reaches 130 to 140. At 0.60, the index falls to 110 to 120, and at the extreme value of 0.80, it remains at 90 to 100, essentially flat over the 26-year horizon. This pattern indicates that the contagion coefficient is the single most influential parameter for the long-run trajectory of financial variables.

Figure 4 presents the Monte Carlo fan charts for four key variables based on 500 random parameter draws.

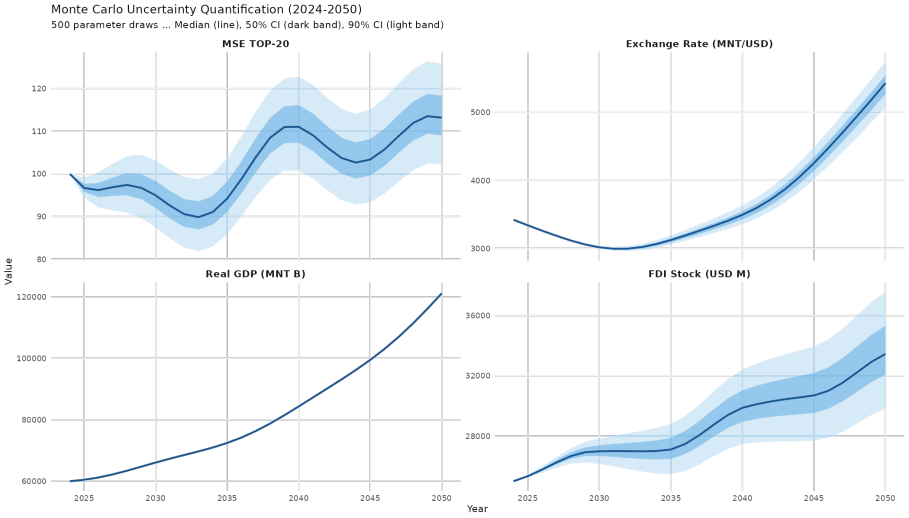


Figure 4. Monte Carlo uncertainty quantification for 2024–2050

The 90 percent confidence interval for the MSE TOP-20 index in 2050 is [128, 163], with a median of 143.5. For real gross domestic product, the 90 percent confidence interval is [111.1, 112.7] trillion tugrik with a median of 111.9 trillion, indicating that this variable is tightly anchored to its trend growth path of 4.5 percent per year. The 90 percent confidence interval for foreign direct investment in 2050 is [30.5, 38.4] billion United States dollars with a median of 34.3 billion. Detailed Monte Carlo results across three forecast horizons appear in Table 3.

Table 3. Monte Carlo simulation results for key variables

Variable	Year	5th percentile	Median	95th percentile
MSE TOP-20	2030	88.6	96.2	104.5
MSE TOP-20	2040	109.6	121.2	134.9
MSE TOP-20	2050	127.7	143.5	162.9
Real GDP (B MNT)	2030	65,934	65,993	66,064
Real GDP (B MNT)	2040	81,863	82,057	82,261
Real GDP (B MNT)	2050	111,110	111,893	112,709
FDI (USD M)	2030	26,166	26,997	27,842
FDI (USD M)	2040	27,588	29,996	32,536
FDI (USD M)	2050	30,536	34,266	38,412

Note: *compiled by the authors based on 500 Monte Carlo parameter draws*

5 | DISCUSSION AND POLICY IMPLICATIONS

The simulation results carry several implications for Mongolian policymakers. First, the long-run economic outlook is broadly positive, with substantial real income growth projected through 2050 even under stress scenarios. However, this trajectory is conditional on maintaining macroeconomic stability and credible institutional commitments. Second, mega projects offer meaningful but not transformative gains. The combined scenario adds approximately 1.3 percent to real gross domestic product by 2050 relative to baseline, while creating substantial short-run macroeconomic stress. This finding suggests that project sequencing and gradualism are likely to be more effective than simultaneous implementation.

Third, external shocks produce sharp short-run disruptions but limited long-run damage. The Mongolian economy demonstrates relatively rapid recovery capacity, particularly when supported by appropriate macroprudential and monetary policy responses. Fourth, investor sentiment emerges as a critical variable in the propagation of contagion. The sensitivity analysis confirms that small changes in the contagion coefficient produce substantial differences in long-run financial market trajectories, underlining the importance of policies that support sentiment stability through transparency and credibility.

Based on these findings, several specific policy recommendations emerge. First, Mongolia should establish a commodity revenue stabilization fund following the model of Norway, Chile, or Botswana. The simulation results indicate that countercyclical fiscal policy could substantially reduce volatility relative to the procyclical pattern observed in the baseline. Second, mega projects should be sequenced rather than implemented simultaneously, with recommended ordering Erdeneburen Hydropower Plant followed by the railway followed by the Mining Expansion, with two to three year gaps between project starts. Third, foreign exchange reserves should be maintained at approximately six months of imports (more than 5 billion United States dollars) to provide adequate buffer capacity during external shock periods. Fourth, the central bank should commit to the Taylor rule even during periods of mega project-induced inflation pressure, since temporary deviations

would undermine the long-run credibility that the model's simulations show is essential for financial stability. Fifth, fiscal consolidation should target a reduction in external debt to gross domestic product from 70 percent to 60 percent by 2030. Sixth, domestic savings mobilization should be enhanced to reduce dependence on foreign direct investment, which currently exceeds 14 percent of gross domestic product, well above the typical emerging market average of 5 to 6 percent.

6 | CONCLUSIONS

This study has developed and analyzed a comprehensive system dynamics model of financial contagion in Mongolia covering the 26-year period from 2024 to 2050. The model integrates 15 endogenous stock variables and more than 40 calibrated parameters, drawing on the system dynamics framework established by Forrester (1961) and Sterman (2000) and incorporating insights from contemporary contagion theory including Forbes and Rigobon (2002), Kaminsky and Reinhart (2000), and Mendoza (2010). The model successfully reproduces historical Mongolian macroeconomic dynamics from 2010 to 2024 with root mean squared errors below 12 percent for all major variables, satisfying the standard validation thresholds for system dynamics models.

Several substantive findings emerge from the analysis. First, Mongolia's long-run growth trajectory is robust across scenarios, with real gross domestic product approximately doubling between 2024 and 2050 in all cases. Second, mega-scale infrastructure projects produce meaningful but bounded benefits, with combined synergy effects of approximately 10 percent over individual project sums. Third, external financial shocks generate sharp but transient disturbances, with limited long-run scarring effects. Fourth, the contagion coefficient and investor sentiment dynamics are the most influential parameters for the long-run trajectory of financial variables, indicating that policies supporting market confidence and information transparency are particularly valuable. Fifth, the combined implementation of multiple mega projects creates substantial macroeconomic stress through inflation pressure and exchange rate volatility, suggesting that sequencing strategies are preferable.

The policy recommendations derived from these findings include the establishment of a commodity revenue stabilization fund, sequenced rather than simultaneous mega project implementation, maintenance of adequate foreign exchange reserves, credible commitment to the Taylor rule, fiscal consolidation to reduce external debt, and the development of domestic savings mobilization to reduce excessive reliance on foreign direct investment. These recommendations are grounded in counterfactual simulations rather than purely theoretical arguments, providing a stronger evidential basis for policy design.

The study has several limitations that suggest directions for further research. First, the banking sector is represented in aggregate form, omitting the interbank network structure that Allen and Gale (2000) emphasize. Second, money supply is treated as exogenous rather than endogenous through credit creation. Third, demographic dynamics, including labor force evolution from approximately 1.7

million in 2024 to a projected 2.0 million by 2050, are held constant. Fourth, climate change effects on the agricultural sector, particularly the dzud risk to livestock that accounts for approximately 12 percent of gross domestic product, are not incorporated. Fifth, technological change including artificial intelligence-induced productivity shocks is not modeled. Future research should extend the framework to incorporate these factors and to develop hybrid models that combine system dynamics with dynamic stochastic general equilibrium frameworks for greater microeconomic granularity.

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APPENDIX A. SOURCE CODE

This appendix presents the complete source code used to implement the financial contagion system dynamics model for Mongolia. The code was developed in the R statistical computing environment (version 4.3.3) and uses the deSolve package (Soetaert, Petzoldt, & Setzer, 2010) for numerical integration of the system of ordinary differential equations. The code is organized into eight sections: package loading and setup, parameter specification, initial state, helper functions, the ordinary differential equation system, scenario execution, Monte Carlo simulation, and output generation. Each section is presented below with an accompanying explanation of its purpose and key implementation choices.

A.1. Package loading and environment setup

This block loads the six required R packages and configures the global plotting theme. The deSolve package provides the LSODA solver for the ordinary differential equation system, ggplot2 supports publication-quality figure rendering, dplyr and tidyr enable tabular data manipulation, openxlsx generates the Excel output files, and jsonlite produces the JSON data file used by the interactive dashboard.

```
# Package loading: deSolve provides LSODA solver, openxlsx for
# Excel output, jsonlite for dashboard data export.
suppressPackageStartupMessages({
  library(deSolve)
  library(ggplot2)
  library(dplyr)
  library(tidyr)
  library(openxlsx)
  library(jsonlite)
})

# Plot theme (sans-serif font for cross-platform reliability)
theme_set(theme_minimal(base_size = 11) +
          theme(text = element_text(family = "sans"),
                panel.grid.minor = element_blank()))

out_dir <- "results"
if (!dir.exists(out_dir)) dir.create(out_dir, recursive = TRUE)
```

A.2. Parameter specification

The params list contains all model parameters, organized by subsystem. Stock market parameters control the elasticity of the index to sentiment, the exchange rate, commodity prices, and the contagion index, as well as the mean reversion speed. Sentiment parameters include the adjustment speed (lambda_s), the market response weight (theta_s), and the herding coefficient (rho_s). Inflation parameters capture the exchange rate pass-through (alpha_pi, calibrated to 0.08 following Choudhri and Hakura, 2006), the demand pressure coefficient, and the inflation target. The Taylor rule coefficients (alpha_ip = 1.5, beta_ip = 0.5) satisfy the Taylor principle. Long-run trend parameters reflect underlying real GDP growth (4.5 percent), credit deepening (6 percent), and FDI accumulation (3 percent). Equilibrium values are anchored to actual 2024 observations from the National Statistics Office of Mongolia and the Bank of Mongolia.

```
params <- list(
  # Stock market: elasticities and mean-reversion speed
  alpha_sm = 0.18,    # sentiment -> SM elasticity
  beta_sm  = 0.12,    # FX -> SM elasticity
  gamma_sm = 0.25,    # commodity -> SM pass-through
  delta_sm = 0.45,    # mean-reversion speed
  phi_sm   = 0.20,    # global contagion intensity

  # Exchange rate (FX) dynamics
  alpha_er = 0.06,    # FDI -> ER elasticity
  beta_er  = 0.10,    # trade balance -> ER
  gamma_er = 0.04,    # inflation gap -> ER
  kappa_er = 0.05,    # FX reserves -> ER
  delta_er = 0.18,    # ER mean-reversion speed

  # Sentiment dynamics
```

```
  lambda_s = 0.55,    # adjustment speed (half-life ~1.3 yr)
  theta_s  = 0.45,    # market response weight in S*
  rho_s    = 0.35,    # herding coefficient

  # Inflation dynamics
  pi_target = 0.06,   # central bank target
  alpha_pi  = 0.08,   # ER pass-through (Choudhri-Hakura)
  beta_pi   = 0.06,   # demand pressure
  gamma_pi  = 0.05,   # commodity pass-through
  delta_pi  = 0.40,   # mean-reversion to target

  # Real economy
  mpc      = 0.72,    # marginal propensity to consume
  mpi      = 0.15,    # marginal propensity to import
  tau      = 0.25,    # average tax rate
  delta_k  = 0.06,    # capital depreciation rate

  # FDI dynamics
  alpha_fdi = 0.05,   # sentiment -> FDI
  beta_fdi  = 0.08,   # commodity -> FDI
  delta_fdi = 0.05,   # contagion -> FDI outflow

  # Contagion index components
  rho   = 0.40,       # internal sentiment weight
  zeta  = 0.30,       # global risk weight
  eta   = 0.25,       # inflation stress weight

  # Bank credit
  alpha_b = 0.10, beta_b = 0.08,
  delta_b = 0.20, phi_b = 0.15,

  # Policy interest rate (Taylor rule)
  alpha_ip   = 1.50,  # inflation gap coefficient
  beta_ip    = 0.50,  # output gap coefficient
  ip_neutral = 0.07,  # neutral rate
  delta_ip   = 0.30,  # adjustment speed

  # Real GDP and tax
  delta_y   = 0.20,   # GDP adjustment speed
  tax_elast = 1.10,   # commodity uplift on tax
  delta_t   = 0.25,   # tax adjustment speed

  # Long-run trend growth
  trend_gdp    = 0.045, # 4.5% p.a. real GDP trend
  trend_fdi    = 0.030, # 3.0% p.a. FDI accumulation
  trend_credit = 0.060, # 6.0% p.a. credit deepening

  # 2024 baseline values for exogenous variables
  P_copper_0 = 9266, P_coal_0 = 137,
  P_gold_0 = 2400, GRA_0 = 0.55,

  # Equilibrium values (calibrated on 2024 actuals)
  SM_eq  = 100,    ER_eq = 3420,
  X_eq   = 15500,  M_eq  = 11700,
  FDI_eq = 25000,  G_eq  = 22000,  R_eq = 5170,
  B_eq   = 32000,  Y_eq  = 60000,  T_eq = 18000,

  # Scenario-specific knobs
  mega_size = 0, mega_start = 1, mega_end = 5,
  mega_fdi_share = 0.60,
  shock_time = -1, shock_size = 0,
  recurring_shock = FALSE
)
```

A.3. Initial state vector (2024 values)

The state vector contains the 15 endogenous stock variables at the start of the simulation horizon.

All values are in their natural units (the stock market index is normalized so that 2024 equals 100, the exchange rate is in MNT per USD, exports and imports are in millions of US dollars per year, and so forth). These initial values are taken directly from official 2024 statistics and represent the starting point from which the system evolves over the 26-year forecast horizon.

```
state <- c(
  SM  = 100.0,    # MSE TOP-20 index, normalized 2024 = 100
  ER  = 3420.0,   # MNT/USD exchange rate
  S   = 0.55,     # investor sentiment [0,1]
  PI  = 0.066,    # CPI inflation rate (annual)
  X   = 15500.0,  # exports (USD M / year)
  M   = 11700.0,  # imports (USD M / year)
  FDI = 25000.0,  # FDI stock (USD M)
  G   = 22000.0,  # government spending (MNT B / year)
  D   = 35000.0,  # external debt (USD M)
  R   = 5170.0,   # FX reserves (USD M)
  K   = 45000.0,  # capital stock (MNT B)
  B   = 32000.0,  # bank credit (MNT B)
  IP  = 0.10,     # policy interest rate
  Y   = 60000.0,  # real GDP (MNT B)
  TX  = 18000.0   # tax revenue (MNT B / year)
)
```

A.4. Helper functions for exogenous inputs and contagion

Three helper functions handle non-state-variable computations. The exogenous_inputs function generates time-varying global commodity prices and global risk appetite, including embedded user-specified shocks and recurring global financial crisis-type events at years 8 (2032) and 20 (2044) for the external shock scenario. The mega_project_effect function returns a Gaussian impulse profile for infrastructure projects, peaking in the middle of the project window. The contagion_index function combines internal sentiment, global risk appetite, and inflation stress into a bounded [0,1] index following the structure of Forbes and Rigobon (2002) and Bekaert, Ehrmann, Fratzscher, and Mehl (2014).

```
# Exogenous inputs: commodity prices and global risk appetite
exogenous_inputs <- function(t, p) {
  # Long-cycle commodity prices (super-cycle ~10 yr period)
  P_copper <- p$P_copper_0 * (1 + 0.18 * sin(0.6 * t) +
                              0.05 * sin(0.12 * t))
  P_coal   <- p$P_coal_0   * (1 + 0.20 * sin(0.6 * t - 0.3) +
                              0.06 * sin(0.10 * t - 1))
  P_gold   <- p$P_gold_0   * (1 + 0.10 * cos(0.4 * t) +
                              0.04 * t * 0.01)

  # Global risk appetite
  GRA <- p$GRA_0 + 0.10 * sin(0.5 * t + 1.2)

  # User-specified shock (Gaussian impulse)
  if (p$shock_time > 0 && abs(t - p$shock_time) < 0.4) {
    GRA <- GRA - p$shock_size *
                 exp(-((t - p$shock_time)^2) / 0.08)
  }

  # Recurring GFC-type shocks at years 8 (2032) and 20 (2044)
  if (p$recurring_shock) {
    for (sk in c(8, 20)) {
      if (abs(t - sk) < 0.5) {
        GRA <- GRA - 0.30 * exp(-((t - sk)^2) / 0.10)
      }
    }
  }
  GRA <- max(0.10, min(0.95, GRA))
  list(P_copper = P_copper, P_coal = P_coal,
       P_gold = P_gold, GRA = GRA)
}
```

```
# Gaussian impulse for mega-project profile
mega_project_effect <- function(t, p) {
  if (t < p$mega_start || t > p$mega_end ||
      p$mega_size == 0) return(0)
  mid  <- (p$mega_start + p$mega_end) / 2
  span <- (p$mega_end   - p$mega_start) / 2
  p$mega_size * exp(-((t - mid)^2) / (2 * (span/1.5)^2))
}

# Contagion index: bounded composite of three stress sources
contagion_index <- function(S, GRA, PI, p) {
  base   <- p$rho  * (1 - S)
  globe  <- p$zeta * (1 - GRA)
  stress <- p$eta  * max(0, PI - p$pi_target)
  max(0, min(1, base + globe + stress))
}
```

A.5. The ordinary differential equation system

The sd_model function implements the system of 15 nonlinear ordinary differential equations. The function takes the current time t, the state vector, and the parameter list, and returns the derivative dx/dt for each state variable along with diagnostic auxiliary variables (contagion index, commodity composite, mega project intensity, and global risk appetite). Each stock variable equation combines a multiplicative shock term capturing short-run dynamics with a mean reversion term toward a time-varying long-run equilibrium. The time-varying equilibria embed the underlying trend growth rates, ensuring that the simulation produces plausible long-horizon trajectories rather than reverting to stationary 2024 values.

```
sd_model <- function(t, state, parms) {
  # Unpack the state vector
  SM <- state["SM"]; ER <- state["ER"]; S <- state["S"]
  PI <- state["PI"]; X <- state["X"];   M <- state["M"]
  FDI <- state["FDI"]; G <- state["G"]; D <- state["D"]
  R <- state["R"]; K <- state["K"]
  B <- state["B"]; IP <- state["IP"]
  Y <- state["Y"]; TX <- state["TX"]

  p <- parms
  exo <- exogenous_inputs(t, p)

  # Composite commodity index (weighted by export shares)
  P_comm <- 0.55 * (exo$P_copper / p$P_copper_0) +
            0.30 * (exo$P_coal   / p$P_coal_0)   +
            0.15 * (exo$P_gold   / p$P_gold_0)
  GRA      <- exo$GRA
  mega     <- mega_project_effect(t, p)
  cont_idx <- contagion_index(S, GRA, PI, p)
  trade_bal <- (X - M) / max(X, 1)

  # Time-varying equilibria for long horizon
  SM_eq_t  <- p$SM_eq  * (1 + 0.02 * t)        # 2% drift
  Y_eq_t   <- p$Y_eq   * exp(p$trend_gdp * t)  # 4.5% trend
  FDI_eq_t <- p$FDI_eq * (1 + p$trend_fdi * t)
  B_eq_t   <- p$B_eq   * exp(p$trend_credit * t)
  ER_eq_t  <- p$ER_eq  * exp(0.035 * t)  # 3.5% deprec.

  # 1. Stock market (SM)
  sm_shock <- (p$alpha_sm * (S - 0.5) -
               p$beta_sm  * (ER / p$ER_eq - 1) +
               p$gamma_sm * (P_comm - 1) -
               p$phi_sm   * cont_idx +
               0.04 * mega) * SM
  dSM <- sm_shock - p$delta_sm * (SM - SM_eq_t)

  # 2. Exchange rate (ER) - 3.5% p.a. trend depreciation
  er_shock <- (-p$alpha_er * (FDI / FDI_eq_t - 1) -
                p$beta_er  * trade_bal +
```

```
              p$gamma_er * (PI - p$pi_target) -
              p$kappa_er * (R / p$R_eq - 1) -
              0.02 * mega) * ER
dER <- er_shock - 0.8 * p$delta_er * (ER - ER_eq_t)

# 3. Investor sentiment (S)
market_perf <- (SM / SM_eq_t - 1)
S_target <- 0.5 + 0.4 * (p$theta_s * market_perf +
                         (1 - p$theta_s) * (P_comm - 1)) -
            p$rho_s * cont_idx
S_target <- max(0.05, min(0.95, S_target))
dS <- p$lambda_s * (S_target - S)

# 4. Inflation (PI)
pi_pressure <- p$alpha_pi * (ER / p$ER_eq - 1) +
               p$beta_pi  * (G / p$G_eq - 1) +
               p$gamma_pi * (P_comm - 1) +
               0.01 * mega
dPI <- pi_pressure - p$delta_pi * (PI - p$pi_target)

# 5. Exports (X)
dX <- 0.20 * (P_comm - 1) * X + 0.03 * mega * X -
      p$delta_x * (X - p$X_eq) + 0.020 * X

# 6. Imports (M)
dM <- p$mpi * (G / p$G_eq - 1) * M -
      0.10 * (ER / p$ER_eq - 1) * M +
      0.08 * mega * M -
      p$delta_m * (M - p$M_eq) + 0.030 * M

# 7. FDI
fdi_inflow  <- p$alpha_fdi * S * FDI +
               p$beta_fdi * max(0, P_comm - 1) * FDI +
               p$mega_fdi_share * mega * 1500
fdi_outflow <- p$delta_fdi * cont_idx * FDI
dFDI <- fdi_inflow - fdi_outflow -
        0.04 * (FDI - FDI_eq_t)

# 8. Government spending (G)
dG <- 0.10 * (P_comm - 1) * G -
      0.18 * (G - p$G_eq) +
      (1 - p$mega_fdi_share) * mega * 800 + 0.025 * G

# 9. External debt (D)
dD <- 0.3 * max(0, M - X) -
      0.05 * D * (R / max(R + D, 1))

# 10. FX reserves (R)
dR <- 0.20 * (X - M) +
      0.015 * FDI -
      0.30 * R * (ER / p$ER_eq - 1) -
      0.04 * R * cont_idx -
      0.10 * (R - p$R_eq)

# 11. Capital stock (K)
invest <- (1 - p$tau) * 0.10 * G +
          0.04 * FDI / p$FDI_eq * 5000 +
          0.04 * mega * K
dK <- invest - p$delta_k * K

# 12. Bank credit (B)
b_inflow  <- p$alpha_b * (FDI / p$FDI_eq - 1) * B +
             p$beta_b  * (S - 0.5) * B
b_outflow <- p$phi_b * cont_idx * B +
             0.05 * (IP - p$ip_neutral) * B
dB <- b_inflow - b_outflow -
```

```
        p$delta_b * (B - B_eq_t)

  # 13. Policy rate (IP) - Taylor rule
  output_gap <- (Y / Y_eq_t - 1)
  ip_target <- p$ip_neutral +
               p$alpha_ip * (PI - p$pi_target) +
               p$beta_ip  * output_gap
  ip_target <- max(0.02, min(0.30, ip_target))
  dIP <- p$delta_ip * (ip_target - IP)

  # 14. Real GDP (Y) - Keynesian aggregate demand
  consumption <- p$mpc * (Y - TX)
  investment  <- 0.20 * K + 0.10 * (B - B_eq_t)
  govt_demand <- G * 0.50
  net_exports <- (X - M) * 3.5
  Y_target <- consumption + investment +
              govt_demand + net_exports +
              0.20 * mega * Y_eq_t
  Y_target <- 0.5 * Y_target + 0.5 * Y_eq_t +
              0.20 * mega * Y_eq_t
  Y_target <- max(Y_eq_t * 0.5, Y_target)
  dY <- p$delta_y * (Y_target - Y)

  # 15. Tax revenue (TX)
  tx_target <- p$tau * Y *
               (1 + p$tax_elast * 0.05 * (P_comm - 1))
  dTX <- p$delta_t * (tx_target - TX)

  # Return derivative vector + diagnostic auxiliaries
  list(c(dSM, dER, dS, dPI, dX, dM, dFDI, dG,
         dD, dR, dK, dB, dIP, dY, dTX),
       cont_idx = cont_idx, P_comm = P_comm,
       mega = mega, GRA = GRA)
}
```

A.6. Scenario execution

This block runs the six deterministic scenarios analyzed in the paper. The run_scenario helper function calls the LSODA solver via the ode function from the deSolve package, requesting quarterly output (delta t = 0.25 years) over the 26-year horizon. Each scenario differs only in the values of mega project parameters (size, start year, end year, FDI share) and the external shock parameters (timing, magnitude, recurring flag). All scenarios are then combined into a single data frame for downstream analysis and plotting.

```
# Time grid: quarterly resolution over 26 years
times <- seq(0, 26, by = 0.25)

run_scenario <- function(p, label) {
  cat(sprintf(">>> %s ...\n", label))
  out <- ode(y = state, times = times,
             func = sd_model, parms = p,
             method = "lsoda", maxsteps = 100000)
  df <- as.data.frame(out)
  df$scenario <- label
  df$year <- 2024 + df$time
  df
}

# Six scenarios
out_base <- run_scenario(params, "Baseline")

p_eb <- params
p_eb$mega_size <- 0.30
p_eb$mega_start <- 1.0
p_eb$mega_end <- 5.0
p_eb$mega_fdi_share <- 0.50
out_eb <- run_scenario(p_eb, "Erdeneburen HPP")
```

```
p_rail <- params
p_rail$mega_size <- 0.45
p_rail$mega_start <- 0.5
p_rail$mega_end <- 4.0
p_rail$mega_fdi_share <- 0.40
out_rail <- run_scenario(p_rail, "TT-GS Railway")

p_min <- params
p_min$mega_size <- 0.55
p_min$mega_start <- 1.5
p_min$mega_end <- 6.0
p_min$mega_fdi_share <- 0.80
out_min <- run_scenario(p_min, "Mining Expansion")

p_combo <- params
p_combo$mega_size <- 0.95
p_combo$mega_start <- 0.5
p_combo$mega_end <- 6.0
p_combo$mega_fdi_share <- 0.65
out_combo <- run_scenario(p_combo, "Combined Mega")

p_shock <- params
p_shock$shock_time <- 2.0
p_shock$shock_size <- 0.35
p_shock$recurring_shock <- TRUE
out_shock <- run_scenario(p_shock, "External Shock")

# Combine all scenarios
all_results <- bind_rows(out_base, out_eb, out_rail,
                         out_min, out_combo, out_shock)
```

A.7. Monte Carlo simulation

The Monte Carlo simulation propagates parameter uncertainty into the forecasts. Ten key parameters identified as the most influential through preliminary sensitivity analysis are sampled from truncated normal distributions, with means equal to the calibrated baseline values and standard deviations corresponding to estimation uncertainty. Each of the 500 random parameter draws produces a complete 26-year simulation; the percentile fan charts presented in Figure 4 are computed from these draws. The truncation prevents implausible parameter values (such as negative contagion coefficients or output gap coefficients exceeding 1.0).

```
n_mc <- 500
set.seed(42)  # reproducibility

# Parameter distributions: c(mean, sd, lower, upper)
mc_param_specs <- list(
  rho      = c(0.40, 0.08, 0.15, 0.65),
  zeta     = c(0.30, 0.06, 0.10, 0.50),
  eta      = c(0.25, 0.05, 0.10, 0.40),
  alpha_sm = c(0.18, 0.04, 0.05, 0.30),
  phi_sm   = c(0.20, 0.05, 0.05, 0.40),
  alpha_pi = c(0.08, 0.02, 0.02, 0.18),
  alpha_b  = c(0.10, 0.025, 0.03, 0.20),
  phi_b    = c(0.15, 0.04, 0.05, 0.30),
  alpha_ip = c(1.50, 0.20, 1.00, 2.00),
  beta_ip  = c(0.50, 0.15, 0.10, 1.00)
)

mc_results <- data.frame()
mc_times   <- seq(0, 26, by = 1)  # annual for MC

for (i in seq_len(n_mc)) {
  p_i <- params
  for (pname in names(mc_param_specs)) {
    spec <- mc_param_specs[[pname]]
    val  <- rnorm(1, mean = spec[1], sd = spec[2])
```

```
    val  <- max(spec[3], min(spec[4], val))
    p_i[[pname]] <- val
  }
  out_i <- tryCatch({
    ode(y = state, times = mc_times,
        func = sd_model, parms = p_i,
        method = "lsoda", maxsteps = 50000)
  }, error = function(e) NULL)
  if (is.null(out_i)) next
  df_i <- as.data.frame(out_i)
  df_i$run_id <- i
  mc_results <- bind_rows(mc_results, df_i)
}

# Compute percentiles for fan charts
mc_summary <- mc_results %>%
  group_by(time) %>%
  summarise(
    SM_p05  = quantile(SM,  0.05, na.rm = TRUE),
    SM_p50  = quantile(SM,  0.50, na.rm = TRUE),
    SM_p95  = quantile(SM,  0.95, na.rm = TRUE),
    Y_p05   = quantile(Y,   0.05, na.rm = TRUE),
    Y_p50   = quantile(Y,   0.50, na.rm = TRUE),
    Y_p95   = quantile(Y,   0.95, na.rm = TRUE),
    FDI_p05 = quantile(FDI, 0.05, na.rm = TRUE),
    FDI_p50 = quantile(FDI, 0.50, na.rm = TRUE),
    FDI_p95 = quantile(FDI, 0.95, na.rm = TRUE)
  ) %>%
  mutate(year = 2024 + time)
```

A.8. Figure rendering and data export

The final block produces the figures and data files used in the paper and the interactive dashboard. The ggplot2 package generates publication-quality multi-panel figures showing the 15 stock variable trajectories across all six scenarios, the contagion index dynamics, the parameter sensitivity analysis, and the Monte Carlo fan charts. The simulation results are exported to Excel format (with separate sheets for summary, full results, and Monte Carlo statistics) and to JSON format for use by the interactive HTML dashboard. All figure labels are in English to ensure cross-platform reliability when figures are embedded in DOCX, PDF, and HTML outputs.

```
# Color palette for scenarios
scenario_colors <- c(
  "Baseline"          = "#2C3E50",
  "Erdeneburen HPP"   = "#3498DB",
  "TT-GS Railway"     = "#16A085",
  "Mining Expansion"  = "#E67E22",
  "Combined Mega"     = "#8E44AD",
  "External Shock"    = "#C0392B"
)

# Multi-panel figure: key variables across scenarios
key_long <- all_results %>%
  select(year, scenario, SM, ER, S, PI, B, IP, Y, TX) %>%
  pivot_longer(SM:TX, names_to = "variable")

p_keys <- ggplot(key_long, aes(year, value,
                               color = scenario)) +
  geom_line(linewidth = 0.7) +
  facet_wrap(~ variable, scales = "free_y", ncol = 4) +
  scale_color_manual(values = scenario_colors) +
  labs(title = "Key Financial and Real-Sector Variables",
       subtitle = "26-year forecast, 6 scenarios",
       x = "Year", y = "Value")

ggsave("results/fig_key_variables.png", p_keys,
       width = 14, height = 8, dpi = 150)
```

```
# Contagion index across scenarios
p_cont <- ggplot(all_results,
                 aes(year, cont_idx, color = scenario)) +
  geom_line(linewidth = 0.8) +
  geom_hline(yintercept = 0.5, linetype = "dashed",
             color = "red") +
  scale_color_manual(values = scenario_colors) +
  labs(title = "Financial Contagion Index Dynamics",
       y = "Contagion Index [0,1]", x = "Year")

ggsave("results/fig_contagion_index.png", p_cont,
       width = 12, height = 6, dpi = 150)

# Export to Excel (3 sheets)
wb <- createWorkbook()
addWorksheet(wb, "Summary")
addWorksheet(wb, "FullResults")
addWorksheet(wb, "MonteCarlo")
writeData(wb, "FullResults", all_results)
writeData(wb, "MonteCarlo", mc_summary)
saveWorkbook(wb, "results/simulation_results.xlsx",
             overwrite = TRUE)

# Export to JSON for interactive dashboard
json_out <- list(
  scenarios = unique(all_results$scenario),
  data = all_results,
  mc = mc_summary,
  metadata = list(
    generated_at = format(Sys.time()),
    n_obs = nrow(all_results),
    n_mc_runs = length(unique(mc_results$run_id))
  )
)
writeLines(toJSON(json_out, auto_unbox = TRUE,
                  digits = 4),
           "results/simulation_data.json")

cat("Simulation complete:",
    format(Sys.time()), "\n")
```

A.9. Software environment and reproducibility

To support reproducibility, the model was developed and tested in the following software environment: R version 4.3.3 (2024-02-29), running on a Linux x86_64 system. The required R packages and their versions are: deSolve 1.40, ggplot2 3.5.1, dplyr 1.1.4, tidyr 1.3.1, openxlsx 4.2.7, and jsonlite 1.8.8. All input data (commodity prices, exchange rates, gross domestic product, foreign direct investment stocks, etc.) are sourced from publicly available statistics and are documented in the accompanying data file. The random number generator seed is fixed at 42 to ensure that the Monte Carlo simulation produces identical results across runs. The complete code base, including data preparation scripts and the interactive dashboard, is available from the author upon request.

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ORIGINAL ARTICLE

Developing an Asset Management Audit Framework and Effectiveness Index for Kazakhstan's Quasi-Public Sector

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Abstract
Effective asset management of quasi-public sector organizations is an important condition for improving economic efficiency, quality of corporate governance and sustainability of business processes. The purpose of this study is to develop a conceptual model of asset management audit adapted to the conditions of Kazakhstan and to propose an Asset Management Effectiveness Index (AMEI). The methodology includes a systematic review of the literature on the PRISMA protocol, a thematic analysis of selected studies, and an illustrative analysis of the activities of JSC NC KazMunayGas. Scientific publications for 2012-2020 and consolidated financial statements of KazMunayGas under IFRS for 2022-2023 were used as initial data. Based on the results of the thematic analysis, seven key areas were identified: independence of auditors, application of INTOSAI standards, asset management audit methodology, corporate governance and accountability, features of Kazakhstan's quasi-public sector, audit quality control mechanisms, and financial benchmarking. On this basis, a five-stage audit and AMEI model is proposed, which includes five equally weighted components, evaluated on a scale from 0 to 10. KazMunayGas's illustrative data shows that in 2022-2023, revenue decreased from $18,860 million to $18,236 million. The results show the practical significance of the proposed model for a comprehensive assessment of the asset management system; however, calculating and empirically validating AMEI require access to internal audit documentation and informed business decisions in quasi-public sector organizations.

KEYWORDS
Audit, Asset Management, Risk Management, Economic Efficiency, Corporate Governance, Quasi-Public Sector, KazMunayGas

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1 | INTRODUCTION

Asset management (hereinafter – AM) has evolved from traditional maintenance management into an integrated strategic function concerned with maximising the value that physical assets generate across their full lifecycle (Komljenovic et al., 2015; Mollentze, 2007). In contemporary organisations, effective AM requires coordinated institutional capabilities, systematic resource utilisation, and structured decision-making encompassing asset acquisition, operation, and disposal. Nevertheless, poor coordination, internal governance weaknesses, and operational inefficiencies frequently prevent organisations from realising the full value of their asset portfolios (Davis & Lleo, 2008). AM should therefore be understood not merely as a technical or maintenance function, but as a strategic process requiring systematic governance and accountability mechanisms (Komljenovic et al., 2015).

A structured audit process is recognised as an essential mechanism for evaluating AM effectiveness. By examining organisational practices against established standards and benchmarks, AM audits identify performance gaps and generate recommendations for corrective action (Grenčík & Legát, 2007; Too, 2010). Such audits typically involve analysis of internal policies, review of procedural documentation, interviews with key personnel, and evaluation of operational activities (Raj, 2016; Soh & Martinov-Bennie, 2011). Despite the availability of general audit frameworks, a recognised gap exists in approaches that provide structured, composite measurement of asset management effectiveness based on audit evidence across multiple governance dimensions simultaneously, particularly for state-owned and quasi-public enterprises where accountability requirements are especially demanding (Oussii et al., 2019).

In Kazakhstan, quasi-public sector organisations occupy a central position in the national economy and are subject to heightened audit oversight requirements (Taubayev et al., 2017). The state has implemented a series of initiatives to strengthen the AM performance of these entities, recognising that effective governance of state assets is fundamental to economic development (Burns, 2010). Amanova et al. (2016) identified significant deficiencies in the audit processes applied to quasi-public sector AM in Kazakhstan, finding that a substantial proportion of detected infringements relates to accounting and asset management, and highlighted the need for more rigorous, internationally aligned audit frameworks.

KazMunayGas (hereinafter – KMG), a major state-owned enterprise in Kazakhstan's oil and gas sector, provides an illustrative context for examining asset management effectiveness through audit-based assessment in the quasi-public sector context. As a vertically integrated company managing assets across extraction, transportation, refining, and services, KMG faces AM challenges characteristic of large quasi-public enterprises. The company is subject to internal and external audits in accordance with national regulatory requirements and International Financial Reporting Standards (hereinafter – IFRS), making it a suitable, data-rich case for illustrative framework application.

The purpose of this study is to develop a conceptual model of asset management audit adapted to the conditions of Kazakhstan and to propose an Asset

Management Effectiveness Index (hereinafter – AMEI). The institutional context of the framework is illustrated using KMG's publicly reported consolidated IFRS data for 2022–2023, however, calculation of the AMEI requires internal audit evidence. The results provide auditors, policymakers, and governance reformers with an assessment methodology applicable to Kazakhstan's quasi-public sector and potentially adaptable, subject to further validation, to comparable state-owned enterprise contexts.

2 | LITERATURE REVIEW

Developing an audit-based framework for assessing asset management effectiveness in Kazakhstan's quasi-public sector requires drawing on two main bodies of scholarship: research on AM audit practice, which establishes what an effectiveness assessment must measure (Grenčík & Legát, 2007; Hay & Cordery, 2018; Mollentze, 2007; Parra Márquez et al., 2020); institutional research on Kazakhstan's quasi-public sector, which identifies the ownership arrangements, accountability obligations, and managerial constraints that shape audit practice (Sembiyeva et al., 2019; Taubayev et al., 2017); and publicly reported information on KMG, which supplies the illustrative material for the framework's application. The review addresses these streams in turn.

The development of AM audit as a field has followed a recognizable trajectory from technical to institutional concerns. Earlier studies primarily addressed audit quality, asset lifecycle management, maintenance assessment, and the design of audit procedures (Arruñada, 2000; Mollentze, 2007). Subsequent research increasingly incorporated performance audit principles and INTOSAI-based assessment criteria, expanding the scope of AM auditing from technical compliance to performance assessment (Daujotaitė & Mačerinskienė, 2008; Sembiyeva et al., 2019). A third phase has addressed the governance complexity of public and quasi-public sector contexts, recognizing that audit functions in these organizations simultaneously serve insurance, accountability, signalling, and management control purposes, and that existing frameworks do not adequately address their particular institutional arrangements (Hay & Cordery, 2018; Parra Márquez et al., 2020; Tynybayeva et al., 2023).

Despite this progressive development, the reviewed literature exhibits a consistent limitation: the absence of a structured, sector-specific framework capable of guiding the full AM audit process in quasi-public sector organizations. Yusof (2013) identified the need for rigorous AM assessment models in the public sector but did not produce one; Tynybayeva et al. (2023) acknowledged that no structured model explains the full architecture of AM auditing in quasi-public sector governance; Sembiyeva et al. (2019) reached a similar conclusion for performance audit; and the methodologies of Mollentze (2007) and Parra Márquez et al. (2020) were developed for the private sector and require substantial adaptation before application to quasi-public organizations. This recurring gap is the primary motivation for the framework proposed in the present study.

Kazakhstan presents a particularly acute instance of this general problem. Its

model of quasi-public sector governance concentrates national strategic assets in large state-affiliated entities that combine state control with commercial performance mandates (Saparovich, 2017; Zumanova et al., 2016). These organizations are simultaneously subject to state audit requirements and commercial performance expectations – a combination that existing frameworks address only partially. The scale of these entities, the diversity of their asset portfolios, and Kazakhstan's evolving regulatory and institutional environment limit the direct transferability of frameworks developed for other jurisdictions and require contextual adaptation. A framework purpose-built for this context therefore addresses a gap that the literature has identified but not filled.

Yusof (2013) analyzed the effectiveness of public sector asset management through a case study of Malaysian authorities, whose diverse asset holdings require extensive strategic management. The findings indicate that AM strategy should incorporate income generation for immovable assets, greater awareness among managers and stakeholders, and training in policy and procedural implementation (Ani et al., 2016; Yusof, 2013). From an auditing perspective, rigorous models are needed to assess current practices against standards, with regulators and audit agencies highlighting deficiencies and issuing improvement guidelines (Arruñada, 2000).

Tynybayeva et al. (2023) examined the key issues in auditing AM systems within Kazakhstan's quasi-public sector entities, including KMG and emphasized that an effective audit framework must define the core principles, rules, and compliance requirements governing the audited organization. Clear standards, strict compliance mechanisms, and continuous oversight by audit management are preconditions for effective audit activity, while independence and objectivity remain essential characteristics of a credible audit system (Goodwin & Yeo, 2001). Audit leadership determines resource requirements, forms the audit team, defines responsibilities, and supervises implementation (Alzeban & Gwilliam, 2014). The authors acknowledge, however, the absence of a comprehensive and rigorously structured model capable of explaining the full architecture of AM auditing within public sector governance systems (Tynybayeva et al., 2023).

Sembiyeva et al. (2019) conceptualize performance audit under the standards of the International Organization of Supreme Audit Institutions (INTOSAI) as one of the state's most influential AM mechanisms in quasi-public sector organizations, but note the absence of a model for building an audit system to assess quasi-public sector performance.

Mollentze (2007) developed an audit methodology for organizational asset management, comprising an Asset Management Improvement program and a structured business process for realizing improvement opportunities identified through audit. The methodology rests on the four asset lifecycle phases of acquisition, operation, maintenance, and disposal (Giglio et al., 2018). Its limitation is its private sector orientation, which leaves the audit methodology challenges of the quasi-public sector unaddressed.

Parra Márquez et al. (2020) demonstrated the importance of structured audit in-

struments in maintenance, asset management, and reliability processes, proposing two survey-based techniques – the Maintenance and Safety Survey (MSS) and the Asset Management, Operational Reliability, and Maintenance Survey (AMORMS) – that proved effective for AM governance in industrial settings (Kurbanova et al., 2018). These instruments, however, require extension before they can be applied to quasi-public sector AM processes such as those of Kazakhstani companies.

Governance in the public sector has become a global challenge owing to inefficiency, fraud, corruption, and weak internal management (Mulyadi et al., 2012). Abd Aziz et al. (2015) analyzed the internal factors affecting integrity systems, accountability, leadership, and internal control in public organizations, while monitoring of public sector transparency and efficiency is increasingly regarded as a public right (Ball, 2012). This evidence base supports the development of an audit model for improving asset governance in quasi-public sector organizations.

Hay and Cordery (2018) analyzed the value of public sector audit through the functions of insurance, signaling, agency, management control, and governance, showing that several of these functions, such as management control and agency, can be applied successfully in public sector settings. Their analysis indicates that public sector auditing requires further research before its standards and functions can be applied comprehensively.

A recent systematic review of performance auditing in the public sector corroborates this trajectory, finding that performance audit research has expanded in scope and methodological diversity since 2010 while persistent gaps remain in sector-specific audit frameworks for quasi-public and state-owned enterprises (Rana et al., 2022). This confirms that the governance complexity characteristic of quasi-public entities has not been adequately addressed by existing audit models.

Kazakhstan-focused studies reinforce these findings. Saparovich (2017) identified the underestimation of regulatory functions and the transformation of ownership functions as sources of governance crisis in the quasi-public sector, proposing dynamic methods for long-term strategic management. Zumanova et al. (2016) found that although Kazakh corporate enterprises are competitive in the domestic market, comparison with international standards shows that their management strategies require reform (Bhuiyan & Amagoh, 2011); however, their study did not address AM audit requirements. Dossova (2012) examined human resource management in Kazakhstan's oil and gas sector, including KMG, showing that training, performance appraisal, and career development practices significantly affect employee productivity, but gave limited attention to asset management and its accountability functions.

Based on the reviewed literature, five interrelated dimensions emerge as central to the assessment of asset management effectiveness: compliance with regulatory and organisational requirements, quality of asset management documentation, efficiency of asset utilisation, effectiveness of asset-related risk management, and implementation of previous audit recommendations. These dimensions form the conceptual basis of the proposed AMEI.

3 | METHODOLOGY

This study adopts a multi-method research design integrating three complementary approaches: a systematic literature review (SLR), a single illustrative case study of KMG, and an AMEI that operationalizes the assessment dimension of the proposed audit framework. The SLR constitutes the primary research method and provides the theoretical foundation for the study's principal output – a proposed AM audit framework for Kazakhstan's quasi-public sector. The case study applies the proposed framework to a real institutional context in an illustrative capacity.

This design was selected because the research objectives require both a synthesis of existing knowledge and a demonstration of practical applicability. A purely theoretical approach would not satisfy the study's applied objectives, while a purely empirical approach would be constrained by the limited availability of primary data from quasi-public sector organizations in Kazakhstan. The multi-method design resolves this tension by grounding the framework in the published literature and illustrating its logic through a real-world application.

Google Scholar was selected as the primary bibliographic platform because it provides broad interdisciplinary coverage of peer-reviewed journals, institutional reports, and grey literature relevant to public sector management, audit governance, and asset management in emerging economies; many sources addressing Kazakhstan's quasi-public sector are indexed there but absent from field-specific commercial databases. The systematic search was conducted in 2020 using six predefined keyword strings combining terms for asset management, auditing, and quasi-public sector governance. Supplementary verification searches across Scopus, Web of Science, ScienceDirect, SpringerLink, and Emerald Insight did not indicate that the review corpus omitted major streams of relevant literature. Screening decisions at each stage were applied by the primary researcher against the predefined inclusion and exclusion criteria set out below.

The search was restricted to publications from 2012 to 2020, a window defined to capture the body of scholarship from which the theoretical framework is drawn. More recent publications from 2021 to 2025 were not subject to formal SLR screening; where they provide directly relevant contextual or methodological grounding, they are cited as supplementary references, clearly distinguished from the 11 studies forming the core SLR corpus, and they do not affect the PRISMA-reported screening counts.

For the case study component, the KMG Annual Report 2023 was used as the primary institutional data source, providing the consolidated IFRS financial performance data for fiscal years 2022 and 2023 (KazMunayGas, 2024). This source was excluded from the SLR corpus and treated as primary institutional data for the case study.

To ensure the quality and topical relevance of the reviewed literature, explicit inclusion criteria were applied during the screening process. Studies were eligible for inclusion if they were published in peer-reviewed academic journals or presented as accepted doctoral dissertations, addressed at least one of the predefined search terms related to asset management, auditing, or quasi-public sector governance,

and were available in full-text form. The review was limited to English-language publications issued between 2012 and 2020. The following exclusion criteria were applied:

- Language: Publications available only in languages other than English.
- Quality: Publications in non-peer-reviewed outlets, conference abstracts without full proceedings, or unverified grey literature (with the specific exception of KMG annual reports used for the case study).
- Relevance: Studies with no substantive focus on asset management, audit processes, or public or quasi-public sector governance.

Article screening followed the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to ensure a transparent and replicable study selection process (Page et al., 2021). In stage 1, the initial database search using six predefined keyword strings yielded 700 records. Of these, 200 records were removed before screening because they were duplicates or did not meet the source-type or language requirements, leaving 500 records for title and abstract screening. In stage 2, the titles and abstracts of these 500 records were assessed against the predefined eligibility criteria. A total of 430 records were excluded because they were not relevant to asset management, auditing, or quasi-public sector governance, leaving 70 publications for full-text assessment. In stage 3, the full texts of the 70 shortlisted publications were examined in detail. Of these, 59 were excluded because they fell outside the specified publication period (n = 30), did not substantively address asset management (n = 10), or failed to meet other eligibility criteria (n = 19). The remaining 11 studies met all inclusion criteria and were included in the final systematic review.

Figure 1 presents the complete PRISMA flow diagram.

As shown in Figure 1, the three-stage screening process reduced 700 initially identified records to 11 studies that met all eligibility requirements, a retention rate of approximately 1.6%. The small final corpus is itself a substantive finding: it confirms that peer-reviewed literature specifically addressing AM auditing in Kazakhstan's quasi-public sector remains limited, establishing the need for the synthesizing framework this study proposes.

Formal quality appraisal using a standardised tool, such as the Critical Appraisal Skills Programme checklist or the Mixed Methods Appraisal Tool, was not conducted. This decision reflects the limited number and methodological heterogeneity of studies directly addressing asset management auditing in Kazakhstan's quasi-public sector. Rather than excluding potentially relevant studies on the basis of formal appraisal scores, the review retained all studies meeting the predefined eligibility criteria and considered differences in research design, methodological transparency, and relevance during the thematic synthesis. Accordingly, the findings should be interpreted with caution, as the absence of a formal quality appraisal limits the ability to assess the relative strength of evidence across the included studies. Future reviews should apply an appropriate critical appraisal tool as the evidence base develops.

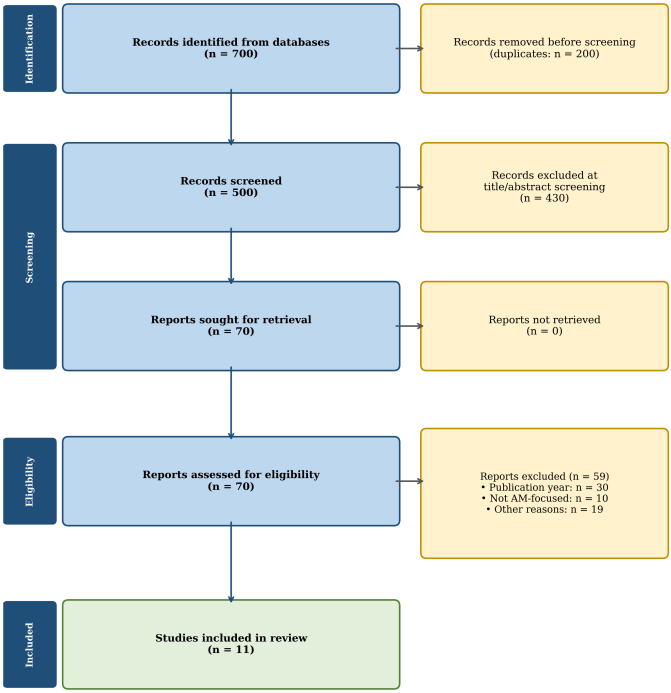


Figure 1. PRISMA flowchart for the systematic review process

Findings were synthesized using a thematic approach, organizing extracted evidence around four core dimensions that emerged inductively from the literature:

- (1) foundational principles of AM auditing, including auditor independence and objectivity;
- (2) applicable international standards, particularly those of INTOSAI;
- (3) financial resource management and performance evaluation within the AM audit process;
- (4) strategic governance and leadership in quasi-public sector organizations. These dimensions directly informed the structure and content of the proposed audit framework presented in the Results section.

The proposed AM audit framework was developed through a three-step iterative process grounded in the thematic synthesis. In step 1, recurring principles identified across the 11 included studies, particularly auditor independence, alignment with INTOSAI principles, structured reporting, and follow-up assessment, were coded and grouped according to their thematic relevance. In step 2, these principles were mapped onto established AM audit methodologies, with Mollentze (2007) providing the principal structural reference and Sembiyeva et al. (2019) and Tynybayeva et al. (2023) informing adaptation to Kazakhstan's institutional context. In step 3, the framework stages – Planning, Auditing, Observations, Re-

porting, and Reassessment – were sequenced to reflect the logical progression of a standards-compliant audit process.

The framework is standards-adaptive, allowing its compliance criteria to be revised in response to changes in relevant INTOSAI principles and national regulatory requirements and adapted to quasi-public sector industries beyond oil and gas. To operationalise the assessment component of the proposed framework, the study develops the AMEI. The AMEI is an audit-based diagnostic measure of the effectiveness of an organisation's asset management system rather than a measure of audit team performance or audit procedure quality. It is calculated as a composite of five equally weighted indicators, each assessed by the audit team on a scale from 0 to 10 using documentary and observational evidence collected during the audit process. The AMEI is calculated using formula (1), based on evidence collected during the audit process:

$$AMEI = \frac{C + D + U + R + I}{5} \tag{1}$$

where:

C – the compliance with applicable asset management regulations, internal policies, and organisational procedures;

D – the completeness, accuracy, consistency, and accessibility of asset management documentation;

U – the effectiveness of physical and financial asset utilisation relative to their designated functions;

R – the identification, documentation, monitoring, and mitigation of asset-related risks;

I – the implementation and verification of recommendations issued during previous asset management audit cycles.

Each component is scored from 0, indicating that the assessment criterion is entirely unmet, to 10, indicating that it is fully satisfied.

KMG was selected as an illustrative organisational context because of the scale and complexity of its asset portfolio and the availability of publicly accessible financial, operational, and governance information. The analysis does not constitute primary field research or a comprehensive organisational audit. No interviews, surveys, internal document reviews, or field observations were conducted. It relies on KMG's Annual Report 2023 and consolidated IFRS data for 2022–2023. These data are used only to illustrate the organisational and financial context in which the framework may be applied and are not sufficient for calculating the AMEI, which requires access to internal audit evidence.

To complement the conceptual audit framework with a practical assessment dimension, this study develops an AMEI as the primary analytical tool for evaluating AM audit quality. The AEI was selected for two methodological reasons. First, it is grounded in observable audit indicators that can be directly collected and verified during the standard stages of the audit process, without reliance on external financial market data or econometric assumptions. Second, the indicators

comprising the AMEI correspond directly to the governance, accountability, and quality control requirements identified across the 11 included studies, ensuring alignment between the assessment tool and the evidence base of the study.

The AMEI is operationalized through five equally weighted components – compliance, documentation quality, asset utilization, risk management, and implementation of prior recommendations – each assessed on a standardized scale, consistent with the structured and verifiable assessment criteria documented for Kazakhstan's quasi-public sector audit context (Sembiyeva et al., 2019; Tynybayeva et al., 2023). The full specification of the AMEI, including the composite formula, variable definitions, and scoring thresholds, is presented in the Results section.

4 | RESULTS

The systematic literature review yielded 11 studies meeting all predefined inclusion criteria. Thematic synthesis of the included studies identified seven recurring themes: auditor independence and objectivity; adherence to INTOSAI performance audit standards; asset management audit methodology; governance and accountability; the institutional characteristics of Kazakhstan's quasi-public sector; audit quality control mechanisms; and financial performance benchmarking. The following paragraphs report the synthesized findings and show how the pattern of evidence across the 11 studies provides the evidentiary foundation for the proposed five-stage AM audit framework.

Table 1 summarises the key characteristics of the 11 studies included in the systematic literature review, including their country or research context, research focus, methodology, and main findings.

As Table 1 shows, the 11 studies included in the systematic review cover various national and industry contexts, including Kazakhstan, Malaysia, Canada, Spain, and international comparisons. The work uses conceptual, empirical, qualitative and mixed methods, as well as a systematic review and case study. Despite differences in methodology, research agrees that the effectiveness of an asset management audit depends on the independence of auditors, compliance with international standards, the quality of internal control, the structuring of audit procedures, and consideration of the institutional features of the quasi-public sector.

To summarize the recurring findings and identify key areas, a thematic matrix was formed, presented in table 2.

The review demonstrates that auditor independence and objectivity are the foundational prerequisites for effective AM auditing across all reviewed contexts. A recurring finding across four included studies is that independence is an organizational design problem rather than a merely procedural requirement: it can be assured only when the audit function is structurally insulated from the entities it audits, with reporting lines to independent oversight bodies and audit committees rather than to management (Abd Aziz et al., 2015; Amanova et al., 2016; Hay & Cordery, 2018; Tynybayeva et al., 2023). Quality control emerges as a direct consequence of independence: three of these studies identify a model in which auditor

Table 1. Study characteristics of the 11 studies included in the systematic review

Author(s) & Year	Country / Context	Research Focus	Methodology	Main Findings
Abd Aziz et al. (2015)	Malaysia	Public sector accountability and integrity systems	Conceptual / survey	Integrity systems and internal controls are foundational to public sector accountability; governance effectiveness depends on structured oversight mechanisms
Amanova et al. (2016)	Kazakhstan	Institutional pressures on audit in the quasi-public sector	Empirical / descriptive	Audit independence is constrained by institutional pressures specific to Kazakhstan's quasi-public sector; structural reforms are required
Dossova (2012)	Kazakhstan	Human resources management in the quasi-public sector	Empirical	HRM practices in Kazakhstan's quasi-public sector require systemic reform; competency gaps in audit staffing are identified
Hay & Cordery (2018)	Multi-country	Value and function of public sector audit	Systematic literature review	Public sector audit simultaneously serves insurance, signalling, agency, and management control functions; no single function is sufficient
Komljenovic et al. (2015)	Canada (mining)	Strategic asset management planning in extractive industries	Mixed methods	Integrating AM strategy with risk management improves operational performance; lifecycle and risk frameworks are interdependent
Parra Márquez et al. (2020)	Spain / international	Audit methodologies for asset management and reliability	Action research / survey	MSS and AMORMS audit tools demonstrate effectiveness for AM governance; structured audit instruments outperform ad hoc approaches
Saparovich (2017)	Kazakhstan	Strategic management in Kazakhstan's quasi-public sector	Conceptual / qualitative	Underestimation of regulatory functions and ownership function tensions are primary drivers of governance crises in Kazakhstan's quasi-public entities
Sembiyeva et al. (2019)	Kazakhstan	Performance audit organization and INTOSAI standards	Empirical	INTOSAI standards provide evaluative criteria but require contextual adaptation for Kazakhstan's regulatory and institutional environment
Tynybayeva et al. (2023)	Kazakhstan	Quasi-public sector audit process and quality control	Empirical / qualitative	Effective AM auditing requires three interdependent dimensions: auditor independence, procedural compliance, and systematic reporting
Yusof (2013)	Malaysia	Public sector asset management effectiveness	Doctoral / case study	Effective AM in the public sector requires rigorous structured assessment models; absence of such models constitutes a field gap
Zumanova et al. (2016)	Kazakhstan	Management strategy for Kazakhstan's state-linked financial corporations	Empirical	Kazakhstan's quasi-public sector entities require management strategy reform; existing international benchmarks are insufficient without adaptation

Note: *compiled by the authors*

independence, procedural compliance, and systematic reporting of findings are interdependent rather than sequential, so that the absence of any one dimen-

sion undermines the other two. Evidence from the Kazakhstan-specific studies indicates that institutional pressures on audit independence are structurally embedded, meaning that independence safeguards must be explicitly designed into any audit framework rather than assumed.

Table 2. Thematic synthesis matrix: findings from the 11 included studies

Theme	No. Studies	Representative Sources	Main Conclusions from the Review
Auditor independence and objectivity	4	Tynybayeva et al. (2023); Hay & Cordery (2018); Amanova et al. (2016); Abd Aziz et al. (2015)	The review consistently identifies auditor independence as the foundational prerequisite for effective AM audit. Institutional pressures on independence are documented across Kazakhstan's quasi-public sector, requiring structural safeguards embedded in the audit framework design.
INTOSAI performance audit standards	3	Sembiyeva et al. (2019); Tynybayeva et al. (2023); Hay & Cordery (2018)	Evidence converges on the necessity of INTOSAI-aligned performance standards while confirming that direct importation without contextual adaptation is insufficient for Kazakhstan's institutional environment.
Asset management audit methodology	3	Parra Márquez et al. (2020); Yusof (2013); Komljenovic et al. (2015)	A recurring finding is the absence of a structured, sector-specific audit methodology for quasi-public entities. Existing tools (MSS, AMORMS) are effective in industrial contexts but require adaptation to governance-intensive AM settings.
Governance and accountability	4	Abd Aziz et al. (2015); Saparovich (2017); Zumanova et al. (2016); Amanova et al. (2016)	Literature converges on accountability as the primary outcome of effective AM audit. Kazakhstan-specific studies identify governance dysfunction as structurally embedded, not incidental, requiring framework-level rather than procedural responses.
Quasi-public sector institutional context	4	Saparovich (2017); Zumanova et al. (2016); Dossova (2012); Amanova et al. (2016)	Kazakhstan's hybrid ownership model generates distinctive audit demands. The reviewed studies demonstrate that frameworks developed for pure public or private sector contexts systematically underaddress the dual accountability pressures of quasi-public entities.
Audit quality control mechanisms	3	Tynybayeva et al. (2023); Abd Aziz et al. (2015); Hay & Cordery (2018)	The evidence indicates that quality control in AM auditing requires the simultaneous embedding of three interdependent mechanisms: procedural compliance, auditor competency, and systematic reporting. No single mechanism is sufficient in isolation.
Financial performance and AM benchmarking	2	Komljenovic et al. (2015); Parra Márquez et al. (2020)	Financial performance metrics are integral to AM audit assessment. The reviewed studies demonstrate that benchmarking against sector-specific standards enables prioritization of audit interventions and identification of measurable improvement targets.

Note: *compiled by the authors*

The review further shows that internationally recognized performance audit standards, particularly those of INTOSAI, provide the evaluative framework necessary for systematic AM auditing, but that their direct application without contextual adaptation is insufficient in Kazakhstan's institutional environment (Hay

& Cordery, 2018; Sembiyeva et al., 2019; Tynybayeva et al., 2023). Standards must be implemented in ways that avoid subjective assessment and ensure systematic coverage of resource allocation, utilization, and disbursement – areas particularly susceptible to governance failure in the quasi-public sector. The literature consistently indicates that external audit quality assessments, conducted according to international standards and reported to audit committees, are essential for continuous improvement.

The audit of financial resources management emerges as a critical but underaddressed dimension of AM auditing. Two included studies provide direct evidence that financial performance benchmarking is integral to effective AM audit assessment, enabling identification of improvement priorities through comparison with sector-specific performance standards (Komljenovic et al., 2015; Parra Márquez et al., 2020). Four Kazakhstan-focused studies further indicate that financial performance deficiencies in the quasi-public sector are structurally linked to governance weaknesses rather than operational failures alone (Amanova et al., 2016; Dossova, 2012; Saparovich, 2017; Zumanova et al., 2016). AM audit frameworks must therefore incorporate explicit financial performance benchmarks and clear accountability mechanisms for performance against defined targets; these findings inform the asset utilisation and risk management dimensions of the AMEI.

Concerning audit methodology itself, three included studies converge on the finding that no single existing methodology adequately addresses the full complexity of AM auditing in quasi-public sector contexts (Komljenovic et al., 2015; Parra Márquez et al., 2020; Yusof, 2013). Structured instruments such as MSS and AMORMS are effective in industrial governance but require adaptation to entities with dual public accountability and commercial performance obligations, while the absence of rigorous structured AM assessment models remains a documented gap in the public sector literature. The proposed five-stage framework responds directly to this methodological gap, synthesizing lifecycle, risk, and compliance dimensions into a single deployable structure.

The review also yields coherent evidence on governance and accountability as structural outcomes of effective AM auditing. Four included studies converge on the finding that accountability deficits in Kazakhstan's quasi-public sector are structurally embedded in the institutional design of these organizations rather than incidental (Abd Aziz et al., 2015; Amanova et al., 2016; Saparovich, 2017; Zumanova et al., 2016). Integrity systems and internal controls provide the governance architecture within which audit functions operate, and audit frameworks for the quasi-public sector must therefore treat accountability as a design requirement embedded throughout each stage of the framework rather than as an output of the audit process.

Finally, the distinctive institutional characteristics of Kazakhstan's quasi-public sector provide the overarching contextual rationale for the proposed framework. Four included studies demonstrate that Kazakhstan's hybrid ownership model, in which national strategic assets are concentrated in state-affiliated commercial entities, creates audit demands that frameworks developed for purely public or

private sector contexts do not adequately address, with dual accountability pressures documented as a source of persistent governance tension and competency gaps in audit staffing as a compounding factor (Amanova et al., 2016; Dossova, 2012; Saparovich, 2017; Zumanova et al., 2016). A framework purpose-built for this context is therefore methodologically necessary and practically justified.

Drawing on this synthesis, the study proposes structuring the audit process according to internationally recognized standards. The process begins with a planning stage in which the audit manager builds a team and determines audit targets, followed by a business risk assessment identifying likely exposures of the AM system, and a standards and procedures stage in which the team – whose independence the framework treats as essential – sets the criteria for achieving the desired performance objectives.

The proposed AM audit framework for Kazakhstan's quasi-public sector is presented in Figure 2.

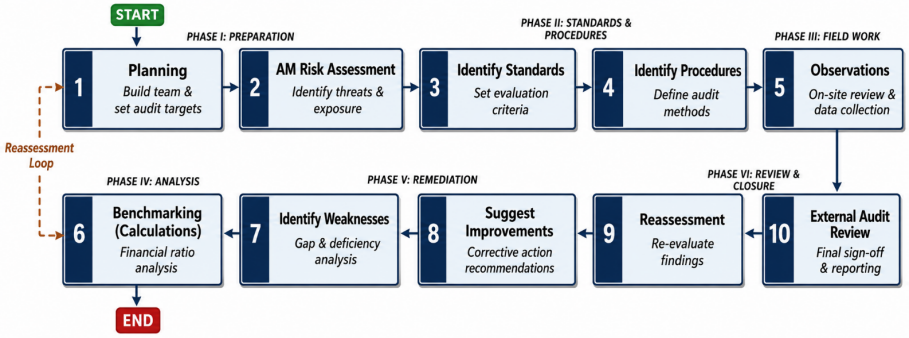


Figure 2. Asset Management Audit Framework for quasi-public sector organisations in Kazakhstan

The audit process starts with the planning phase, during which the audit manager develops a team and identifies targets. The team should understand the processes and resources of the audited enterprise and be trained to accomplish the objectives set at planning. The subsequent business risk assessment identifies threats and vulnerabilities in the AM process; for organizations like KMG, these include resource shortages driven by global market conditions, and the risk management approach determines how resources are managed under inflation, market decline, or routine conditions. The following phase identifies the procedures and standards needed to meet the performance objectives, with the audit team independent in deciding them (Tynybayeva et al., 2023).

The observations phase involves monitoring activities to ensure conformance with the standards and procedures, governing the accountability of the organization's overall assets (Yusof, 2013). The audit officer compares the procedures used on site with standard requirements. Benchmarking then establishes where companies such as KMG stand relative to AM standards; based on this comparison, the audit team identifies weaknesses and suggests improvements to meet the standards and raise professionalism in AM.

Reassessment may or may not be required depending on the scope of identified weaknesses. Where malpractices are observed in critical areas of operations and finance that would severely affect AM, the audit process may be repeated in abbreviated form to assess improvement; minor procedural deficiencies may not require it. The audit process may also be subjected to external review, in which the audit manager invites external agencies or regulators to check its conformity with legal frameworks (Tynybayeva et al., 2023). The audit cycle thus contains built-in scope for improvement, revealed in the final external review phase.

The five-stage structure presented in Figure 2 represents the central contribution of this study. The framework's logic is iterative rather than linear: the Reassessment stage feeds back into Planning for subsequent audit cycles, creating a continuous improvement mechanism suited to the dynamic asset portfolios of Kazakhstan's quasi-public sector organizations. Grounding the framework in INTOSAI standards ensures conformance with internationally recognized benchmarks, while the modular design, in which each stage can be calibrated to sector-specific regulatory requirements, provides adaptability. Relative to Mollentze's (2007) foundational audit methodology, the proposed framework adds a dedicated Reassessment stage that explicitly addresses the recurring governance failures identified in the Kazakhstan literature (Amanova et al., 2016; Tynybayeva et al., 2023).

The audit process model presented in Figure 2 and the systematic review findings indicate that audit effectiveness in Kazakhstan's quasi-public sector cannot be adequately assessed through financial market proxies such as expected returns or systematic risk coefficients. The sector's hybrid ownership structure and the institutional constraints documented across the 11 included studies require an assessment mechanism grounded in directly observable audit evidence. The study therefore proposes a practical AMEI for use within the audit framework.

The AMEI framework is intentionally limited in scope. It does not attempt to quantify asset market values, project financial returns, or estimate systematic risk. Its purpose is to provide audit teams and oversight bodies with a transparent, reproducible, and evidence-based measure of audit process quality applicable within the institutional constraints of Kazakhstan's quasi-public sector. All five component indicators correspond directly to the governance, accountability, and quality control requirements identified in the systematic review synthesis, and each can be assessed from documentation and observations gathered during the standard audit stages shown in Figure 2.

To illustrate the framework's application context, the study draws on KMG's publicly reported information. KMG is transforming its AM model from a management holding to an operator holding, simplifying the management of production assets through a two-tier management structure, divestment of non-core subsidiaries, and conversion of joint-stock companies into limited liability partnerships (KazMunayGas, 2024). Its asset portfolio spans the full value chain of Kazakhstan's oil and gas sector – extraction, transportation, and processing – making it a high-complexity subject for AM auditing. Consolidated IFRS data for 2022–2023 indicate

total revenues of USD 18,860 million and USD 18,236 million, respectively; net income declining from USD 2,835 million to USD 2,026 million alongside an 18.4% decrease in average Brent crude prices; and capital expenditures increasing from USD 1,160 million to USD 1,761 million (KazMunayGas, 2024). These data illustrate the scale and heterogeneity of the asset base to which the framework and the AMEIwould be applied; component scoring itself would require access to internal audit evidence and is therefore beyond the scope of this illustrative application.

5 | CONCLUSION

This study developed a theoretical framework to improve the asset management audit process within Kazakhstan's quasi-public sector. From a systematic literature review that screened 700 initially identified records and synthesized 11 included studies, it identified the principles, standards, and practices critical to more effective audits. The proposed framework envisages planning, risk assessment and determination of relevant standards and procedures, observation and benchmarking of current practices, identification and implementation of improvements, reassessment, and external review. This structure provides a systematic assessment of AM processes aimed at enhanced transparency, accountability, and continuous improvement.

The critical literature findings emphasize auditor independence, observance of international standards – especially those established by INTOSAI – comprehensive training for audit teams, and strategic leadership within the audit process. The framework was illustrated using publicly available data from KazMunayGas, the leading enterprise of Kazakhstan's oil and gas sector. To support practical evaluation of AM audit quality, the study proposed an AMEI grounded in five directly observable indicators: compliance with procedures, documentation quality, asset utilization efficiency, risk management, and implementation of prior audit recommendations. The AMEI provides audit teams and oversight bodies with a transparent and reproducible measure of audit process quality applicable within the institutional constraints of Kazakhstan's quasi-public sector, without reliance on financial market data or externally derived benchmarks.

The contribution of this study is theoretical: the framework and the AMEI have not yet been empirically validated, and the KMG application is illustrative rather than a full organizational audit. Within these bounds, the study offers a structured, evidence-based approach that audit practitioners and regulators in Kazakhstan may adapt, and that may, subject to contextual adaptation and empirical testing, prove informative for other transition economies with comparable state-ownership structures. Future research should validate the framework and the AMEI across a broader sample of quasi-public sector organizations, examine their behaviour over successive audit cycles, and refine component scoring through field applications. The study thereby contributes a structured foundation for improving AM audit practice in quasi-public sector organizations in developing economies.

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The Economic Burden of Road Traffic Crashes in Kazakhstan's Major Cities

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Abstract
Road traffic accidents create significant losses of public welfare associated with premature deaths and injuries, which necessitates their monetary assessment when justifying transport and social policy measures. The purpose of the study is to assess and compare the economic burden of registered road crash outcomes in Almaty and Astana and to evaluate the robustness of the resulting estimates to changes in key calculation parameters. The initial data are organized as a "city–year" panel of 18 observations, based on official statistics from the Bureau of National Statistics of the Republic of Kazakhstan, the Committee on Legal Statistics and Special Accounting, and the World Bank's World Development Indicators. The methodology is based on the Value of a Statistical Life (VSL) and Willingness-to-Pay (WTP) approaches. The results showed that the total monetized burden for 2015-2023 amounted to 809.75 billion tenge in Almaty and 303.88 billion tenge in Astana, or 1.114 trillion tenge in the two cities. The estimated burden in Almaty was 2.66 times that in Astana. Depending on the scenario, the cumulative burden ranged from 776.58 billion to 1,590.08 billion tenge, while the higher losses in Almaty persisted across all robustness checks. The results confirm the importance of accounting for deaths and injuries in the economic assessment of road safety measures and in conducting a cost–benefit analysis. Thus, the city ranking remains stable across the checks, whereas the magnitudes of the decomposition depend on the initial administrative observation.

KEYWORDS
Road Safety, Welfare Burden, Welfare Economics, Transport Economics, Urbanization, Urban Development

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1 | INTRODUCTION

Road traffic crashes impose losses far beyond the transport sector. Deaths and injuries reduce social welfare, generate expenditures, and constrain economic activity. Pain, diminished quality of life, and the risk of premature death have no directly observable market price. Therefore, counts of crashes and casualties alone are insufficient for economic appraisal or for selecting socially efficient interventions.

This issue is particularly relevant to Almaty and Astana, which concentrate a substantial share of Kazakhstan's population and business activity but differ in size, demographic growth, and the registered composition of road traffic injuries. Absolute crash counts largely reflect city size, while per capita rates adjust for population differences but do not capture the monetary value of crash outcomes. Moreover, a mortality-only analysis excludes a substantial share of the burden associated with nonfatal injuries.

The human capital method measures lost output or earnings and therefore captures only part of the welfare value of risk reduction. The willingness-to-pay (hereinafter – WTP) approach uses the value of a statistical life (hereinafter – VSL), which represents aggregate willingness to pay for a small reduction in mortality risk. It is consistent with welfare analysis and cost-benefit analysis, but requires a defensible VSL, appropriate updating over time, and transparent treatment of uncertainty (OECD, 2025; Robinson et al., 2019).

Kazakhstan has a stated preference estimate for road risk. Wijnen (2021) derived a VSL from a population survey and applied it in a national assessment of road crash costs. That estimate, however, refers to 2012 and to the country. The literature contains no comparable city-level series that updates the VSL for real income growth, monetizes fatalities, hospitalized casualties, and other injured persons separately, and tests whether the comparison holds under alternative assumptions.

This study evaluates Almaty and Astana over 2015–2023, excluding 2024 because the administrative definition of an injured person changed. The calculation covers the monetized burden of registered human losses; budgetary damage and reductions in gross regional product (GRP) are excluded. Mortality is valued with an updated Kazakhstan-specific VSL; hospitalization is an administrative proxy for more severe injury; and other injuries are treated separately. Values are expressed in constant 2023 prices and normalized by population and GRP.

The study updates Kazakhstan's WTP-based VSL estimate using real gross national income (GNI), distinguishes hospitalized casualties from other injuries, evaluates three integrated valuation scenarios and an alternative international transfer function, standardizes hospitalization shares, and decomposes changes in the burden into real-VSL and registered-outcomes effects.

The purpose of the study is to assess and compare the economic burden of registered road crash outcomes in Almaty and Astana and to evaluate the robustness of the resulting estimates to changes in key calculation parameters. The analysis constructs a city-year dataset, updates the value of a statistical life, estimates and normalizes the monetized burden, and decomposes its changes using both 2015

and 2016 as base years.

Because the study compares deterministic estimates rather than conducting statistical hypothesis tests, it addresses three research questions:

RQ1: What was the cumulative monetized burden of registered fatalities and injuries in Almaty and Astana during 2015–2023?

RQ2: Does the cross-city ranking remain robust under alternative valuation scenarios, normalization approaches, exclusion of 2015, hospitalization standardization, and a mortality-only calculation?

RQ3: How much of the change in the annual burden is attributable to changes in the real value of statistical life and to registered crash outcomes, and how sensitive is this attribution to the choice of 2015 or 2016 as the base year?

2 | LITERATURE REVIEW

Road crashes create resource costs, production losses, and human welfare losses. The last category includes mortality risk, pain, disability, psychological trauma, and diminished quality of life, while the effects of permanent injury extend to rehabilitation needs, household income, unpaid caregiving, education, employment, and social participation (Bougna et al., 2022; World Bank, 2025; Wijnen & Stipdonk, 2016). These social consequences make medical expenditure an incomplete measure of the burden. Differences in component coverage, valuation methods, severity definitions, and data completeness therefore contribute to substantial variation in estimated road crash costs (Wijnen et al., 2019).

Total social cost, public expenditure, and changes in economic output are distinct concepts. Medical treatment and vehicle repair expenditures may be reflected in measured economic activity, whereas pain, reduced quality of life, and mortality risk are not directly captured in conventional output measures. Expressing monetized welfare losses as a share of gross domestic product or gross regional product therefore provides a scale indicator without implying an equivalent reduction in output (Elvik, 2000; Wijnen, 2021).

Two principal approaches are commonly used to value the human consequences of road crashes. The human capital method estimates lost production or earnings based on age, employment status, and duration of incapacity (Chantith et al., 2021; Connelly & Supangan, 2006). Its productivity focus leaves unpaid work, quality of life, and preferences for risk reduction only partly represented. The willingness-to-pay approach values small changes in mortality risk using the VSL. The VSL represents the aggregate willingness to pay for a risk reduction that prevents one expected statistical fatality. The measure captures the welfare benefit of risk reduction; interpreting it as the price of an identifiable life or as compensation to a family would be incorrect (OECD, 2012; Robinson et al., 2019; Viscusi & Aldy, 2003). Adding a full value of a statistical life to the complete value of future earnings may double-count material well-being already reflected in willingness to pay. Without city-level microdata on income, consumption, age, and disability, a transparent alternative is to use the full value of a statistical life and report the result as a human welfare loss rather than as a total cost.

Benefit transfer is required when a current local stated-preference estimate is unavailable. The value is commonly scaled by an income ratio raised to the power of the elasticity, but empirical elasticities vary substantially across samples and income groups (Hammitt & Robinson, 2011; OECD, 2025; Viscusi & Masterman, 2017). Milligan et al. (2014) estimated an elasticity of 2.478 for developing countries, whereas the transfer model of Wijnen et al. (2026) uses a central value of 1.2 and a range of 1.0–1.4 for low- and middle-income countries. This variation supports updating Kazakhstan's own stated preference estimate as the primary approach and treating the international value-transfer function as a sensitivity check.

Evidence for Kazakhstan and Central Asia establishes both the size of the problem and the limits of available data. Wijnen (2021) combined willingness to pay for human losses with production, medical, property, and administrative costs and estimated Kazakhstan's national road crash cost at USD 6.8 billion in 2012, or 3.3% of gross domestic product. Human losses accounted for about 81% of that estimate. A World Bank (2022) assessment of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan estimated health care costs of road traffic injuries at approximately international USD 95 million in 2016, including USD 49.3 million in Kazakhstan. That study used a cost-of-illness framework and addressed health-system and household consequences, whereas Wijnen (2021) estimated a broader national social cost. Neither provides an annual welfare-based comparison between Kazakhstan's two largest cities. The Central Asia Regional Economic Cooperation report further identifies fragmented police and medical records, inconsistent severity information, and limited record linkage as major obstacles to reliable national and regional comparisons (ADB, 2025).

Nonfatal injuries require explicit treatment because they may produce persistent disability and large household consequences even when mortality is avoided. International practice commonly values nonfatal injuries as fractions of the VSL, although the assigned proportions vary by injury severity, valuation framework, and country (Schoeters et al., 2022; Trawén et al., 2002). For Kazakhstan, Wijnen (2021) applied values equivalent to approximately 13% of the VSL for more severe injuries and 1% for less severe injuries. The central difficulty lies in mapping a statistical category to clinical severity. The internationally used MAIS3+ threshold is not equivalent to administrative hospitalization. Admission may depend on referral pathways, bed capacity, local thresholds, and recording practice. Applying a higher weight to hospitalized casualties can therefore distort comparisons across cities if administrative practices differ.

Police registers usually capture deaths more completely than nonfatal injuries. Underreporting, inconsistent definitions, delayed outcomes, and weak linkage to health records can affect both levels and trends (WHO, 2023). Arbitrary scaling would be unjustified without city-, year-, and severity-specific correction factors. The defensible interpretation is consequently limited to registered casualties, supported by sensitivity checks that vary injury weights, standardize hospitalization shares, exclude an anomalous year, and report mortality separately.

International evidence further highlights the importance of clearly defining the

scope of economic valuation. Wisutwattanasak et al. (2024) estimated a VSL of USD 824,344 for Thailand, whereas Taniform et al. (2023) estimated the total social cost of road traffic crashes in Cameroon at USD 3.6 billion, equivalent to 3.8% of GDP. These figures cannot be compared directly with each other or with a city-level welfare measure, but they demonstrate why a locally grounded benchmark and transparent scenario analysis are necessary.

Finally, changes in monetary burden may reflect both registered outcomes and the monetary value assigned to risk. A Shapley decomposition averages the effects across possible orders of factor substitution and allocates the interaction term symmetrically, producing an exact, residual-free attribution (Shorrocks, 2013). Its result can nevertheless depend on the selected endpoints when the starting observation is administratively unusual. To the best of our knowledge, the literature reviewed here does not provide an annual city-level series for Kazakhstan based on an updated local VSL, an urban comparison that explicitly tests sensitivity to hospitalization classification, or an endpoint-sensitivity analysis of the decomposition between valuation and registered-outcomes effects.

3 | METHODOLOGY

This comparative retrospective study uses 18 city-year observations for Almaty and Astana covering the period 2015–2023. The study period begins with the first consistent regional data series and ends in 2023 because Kazakhstan's administrative definition of an injured person changed in 2024 (Prosecutor General of the Republic of Kazakhstan, 2024).

Data on fatalities, injured persons, and hospitalized casualties were obtained from the Bureau of National Statistics of Kazakhstan, which identifies the Committee on Legal Statistics and Special Records of the Prosecutor General's Office as the primary data source (Bureau of National Statistics, 2025). Population and gross regional product (GRP) data were obtained from the Bureau's regional statistical series (Bureau of National Statistics, 2025). Gross national income (hereinafter – GNI) per capita, the consumer price index (hereinafter – CPI), and the annual average exchange rate were obtained from the World Development Indicators (World Bank, 2025). All data series were downloaded and cross-checked on July 17, 2026.

Hospitalization is used as an administrative proxy for injury severity. Other injured persons were calculated as the difference between the total number of registered injured persons and hospitalized casualties. No adjustment for underreporting was applied because city-, year-, and severity-specific correction factors are unavailable. Consequently, the estimates refer exclusively to registered cases. Table 1 presents the variables, their definitions, units of measurement, data sources, and roles in the analysis.

Table 1. Study variables and parameters

Variable	Definition / unit	Source	Role in the analysis
Registered fatalities	persons	Bureau of National Statistics; primary source: Committee on Legal Statistics and Special Records	Fatal outcomes
Registered injured persons	persons	Bureau of National Statistics; primary source: Committee on Legal Statistics and Special Records	Nonfatal outcomes
Hospitalized casualties	persons	Bureau of National Statistics; primary source: Committee on Legal Statistics and Special Records	Administrative proxy for injury severity
Other injured persons	persons	Author's calculations	Other nonfatal outcomes
Mid-year population	persons	Bureau of National Statistics	Per capita normalization
Gross regional product	KZT million	Bureau of National Statistics	Normalization by economic scale
Gross national income per capita	constant 2020 USD	World Bank, World Development Indicators	Income-based VSL updating
Consumer price index	index	World Bank, World Development Indicators	Conversion to a common price base
Annual average exchange rate	KZT per USD	World Bank, World Development Indicators	Currency conversion
Value of a statistical life	constant 2023 KZT	Calculated from Wijnen (2021)	Unit value of mortality risk

Subscripts c and t denote city and year, respectively.
Registered vehicle counts are excluded because they do not measure distance traveled, through traffic, or actual transport exposure.

Note: compiled by the author

The value used to monetize mortality risk is based on the Kazakhstan-specific stated-preference estimate reported by Wijnen (2021). The low and high VSL estimates for 2012 are USD 595,633 and USD 871,790, respectively, with a mean of USD 733,711 used as the baseline. Real gross national income (GNI) per capita is expressed in constant 2020 USD, as shown in Equation (1):

$$Y_t = GNIpc_t^{KZT} \frac{CPI_{2020}}{CPI_t} \div ER_{2020} \tag{1}$$

where:

Y_t – the real GNI per capita in year, expressed in constant 2020 USD;
$GNIpc_t^{KZT}$ – the nominal gross national income per capita in KZT;
CPI_t – the consumer price index in year;
CPI_{2020} – the consumer price index in the base year 2020;
ER_{2020} – the average KZT/USD exchange rate in 2020.

The 2012 VSL is then updated according to real income growth and converted into constant 2023 KZT using Equation (2):

$$VSL_{t,s}^{2023KZT} = \left[VSL_s^{2012USD}\, ER_{2012}\, \frac{CPI_{2020}}{CPI_{2012}} \div ER_{2020}\right] \left(\frac{Y_t}{Y_{2012}}\right)^{\varepsilon_s} ER_{2020}\, \frac{CPI_{2023}}{CPI_{2020}} \tag{2}$$

where:

$VSL_{t,s}^{2023KZT}$ – the value of a statistical life in year under scenario, expressed in constant 2023 KZT;

$VSL_{s}^{2012USD}$ – the Kazakhstan VSL estimate for 2012 in USD;

ER_{2012} – the corresponding average KZT/USD exchange rates;

ε_s – the income elasticity of the VSL under scenario s.

The same national VSL is applied to both cities in each year so that an identical reduction in mortality risk is assigned the same monetary value. City-specific preferences may nevertheless differ. The annual baseline burden is calculated as shown in Equation (3):

$$B_{ct} = D_{ct} VSL_t + H_{ct} \left(0.13\, VSL_t\right) + \left(I_{ct} - H_{ct}\right) \left(0.01\, VSL_t\right) \tag{3}$$

where:

B_{ct} – the annual monetized burden in city c and year t;

D_{ct} –the number of registered fatalities;

I_{ct} – the total number of registered injured persons;

H_{ct} – the number of hospitalized casualties;

VSL_t – the value of a statistical life in year t.

The baseline injury weights are set at 13% of the VSL for hospitalized casualties and 1% for other injured persons, following the values previously applied to Kazakhstan by Wijnen (2021). Hospitalization is used as an administrative proxy for injury severity and is not equivalent to a clinical MAIS3+ classification. Table 2 presents three integrated valuation scenarios.

Table 2. Parameters of the integrated valuation scenarios

Parameter	Low	Baseline	High
Kazakhstan VSL, 2012, USD	595,633	733,711	871,790
Income elasticity of VSL	1.0	1.2	1.4
Hospitalized injury, share of VSL	10%	13%	16%
Other injuries, share of VSL	0.9%	1.0%	1.5%

Note: compiled by the author

The low and high scenarios represent alternative parameter assumptions and should not be interpreted as statistical confidence intervals. As an additional robustness check, the analysis applies the international VSL transfer function proposed by Wijnen et al. (2026), as specified in Equation (4):

$$VSL_t^{BT} = 404\,000 \left(\frac{Y_t}{5\,726}\right)^{1.2} \tag{4}$$

where:

VSL_t^{BT} – the VSL obtained using the international benefit-transfer specification;

Y_t – the real GNI per capita in year, expressed in constant 2020 USD.

Following Shorrocks (2013), the change in the monetized burden between the base year and 2023 is decomposed into two components: (1) the effect of changes in the VSL and (2) the effect of changes in registered fatalities and injuries. First, the number of registered casualties is converted into a weighted indicator (5):

$$Q_t = D_t + 0.13\, H_t + 0.01\, L_t \tag{5}$$

where:

Q_t – the weighted number of registered casualties in city c and year t;
D_t – the number of fatalities;
H_t – the number of hospitalized casualties;
L_t – the number of other injured persons.

The weights correspond to 100% of the VSL for a fatality, 13% for a hospitalized casualty, and 1% for another injured person. The effect associated with changes in the VSL is calculated as (6):

$$E_{VSL} = (VSL_{2023} - VSL_b)\,\frac{Q_b + Q_{2023}}{2} \tag{6}$$

where:

E_{VSL} – the valuation effect;
Q_b – the equivalent statistical casualties in the corresponding years;
b – the base year, either 2015 or 2016.

Equation (6) shows how the monetized burden changed due to changes in real VSL between the base year and 2023, while the level of registered casualties is represented by their average over the two years. The effect associated with changes in registered fatalities and injuries is calculated as (7):

$$E_Q = (Q_{2023} - Q_b)\,\frac{VSL_b + VSL_{2023}}{2} \tag{7}$$

where:

E_Q–the registered-outcomes effect and the remaining notation is defined above.

The identity $E_{VSL} + E_Q = B_{2023} - B_b$ holds exactly. The decomposition is performed separately using 2015 and 2016 as base years because the hospitalization share in Almaty was unusually high in 2015. Comparing the two base years therefore provides a direct test of the sensitivity of the decomposition results to this initial observation.

The annual city-level data used in the calculations cover registered fatalities, injured persons, hospitalized casualties, population, gross regional product, and the estimated VSL for 2015–2023. The complete dataset, calculation procedures, source links, and access dates are provided in the supplementary materials (Appendix A).

4 | RESULTS

In Almaty, the number of injured persons fell from 6,559 in 2015 to 4,012 in 2023, a reduction of 38.8%, while fatalities declined from 159 to 142, or by 10.7%. Fatalities reached their lowest level in 2020 and 2021, at 84 in each year. In Astana, the number of injured persons increased from 761 to 907, or by 19.2%, while fatalities declined from 57 to 35. These absolute figures should be considered in the context of demographic change: Almaty's population increased from 1.68 million to 2.20 million over the period, while Astana's population grew from 0.87 million to 1.39 million.

Population-normalized indicators declined in both cities. In Almaty, fatalities decreased from 9.48 to 6.47 per 100,000 residents, while injuries declined from 391.16 to 182.76 per 100,000 residents. In Astana, the corresponding rates decreased from 6.56 to 2.51 for fatalities and from 87.57 to 65.14 for injuries. However, population-based rates do not account for transport exposure; exposure-based indicators, such as rates per vehicle-kilometer travelled, would provide a more appropriate measure of road traffic risk.

Hospitalization shares differed markedly between the two cities. In Almaty, the share was 28.6% in 2015 and ranged from 10.3% to 14.4% thereafter. In Astana, it ranged from 69.9% to 73.7% during 2015–2019 and from 54.0% to 58.5% during 2020–2023. The abrupt shift in Almaty between 2015 and 2016 may reflect changes in referral pathways, admission thresholds, or reporting practices, although the available data do not allow these potential administrative explanations to be distinguished. The influence of the 2015 observation is therefore assessed through a separate calculation for 2016–2023 rather than by excluding it from the baseline calculation.

The baseline VSL, expressed in constant 2023 prices, increased from KZT 319.91 million in 2015 to KZT 396.45 million in 2023. The trend was not monotonic, with declines observed in 2016 and 2020 following decreases in real GNI per capita. In 2023, the low, baseline, and high VSL estimates were KZT 302.94 million, KZT 396.45 million, and KZT 500.44 million, respectively.

Table 3 reports the annual monetized burden, its ratio to GRP, and the corresponding per capita values.

In Almaty, the baseline burden declined from KZT 143.87 billion in 2015 to a low of KZT 59.39 billion in 2020, before rising to KZT 91.90 billion in 2023. The minimum coincided with pandemic mobility restrictions, but the descriptive design cannot identify a causal effect of COVID-19 or separate it from other factors. The 2023 value remained 36.1% below the 2015 level. On a per capita basis, the decline was 51.2%, and the ratio to GRP fell from 0.757% to 0.364%. The elevated official count of hospitalized casualties materially affects the 2015 estimate, so the initial level should not be interpreted solely as evidence of a change in the underlying severity of crashes.

Table 3. Annual baseline burden and normalized indicators

Year	Almaty, KZT billion	Almaty, % of GRP	Almaty, KZT per capita	Astana, KZT billion	Astana, % of GRP	Astana, KZT per capita
2015	143.87	0.757	85,798	42.17	0.420	48,522
2016	98.31	0.508	56,771	35.76	0.403	38,498
2017	90.42	0.448	50,763	38.69	0.394	38,388
2018	89.75	0.462	48,966	28.91	0.269	27,250
2019	93.18	0.453	49,293	28.58	0.240	25,666
2020	59.39	0.310	30,430	24.18	0.213	20,728
2021	65.61	0.332	32,710	29.78	0.253	24,443
2022	77.32	0.352	36,272	33.07	0.271	24,955
2023	91.90	0.364	41,861	42.73	0.330	30,692

Note: compiled by the author

In Astana, the burden declined from KZT 42.17 billion in 2015 to KZT 24.18 billion in 2020, but reached KZT 42.73 billion by 2023, 1.3% above its initial absolute level. At the same time, the per capita measure fell from KZT 48,522 to KZT 30,692, or by 36.7%, and the ratio to GRP decreased from 0.420% to 0.330%. The return of the absolute burden to its 2015 level occurred alongside rapid growth in population and the city economy, while the relative indicators continued to improve.

Figure 1 illustrates these contrasting trajectories of the annual monetized burden in Almaty and Astana.

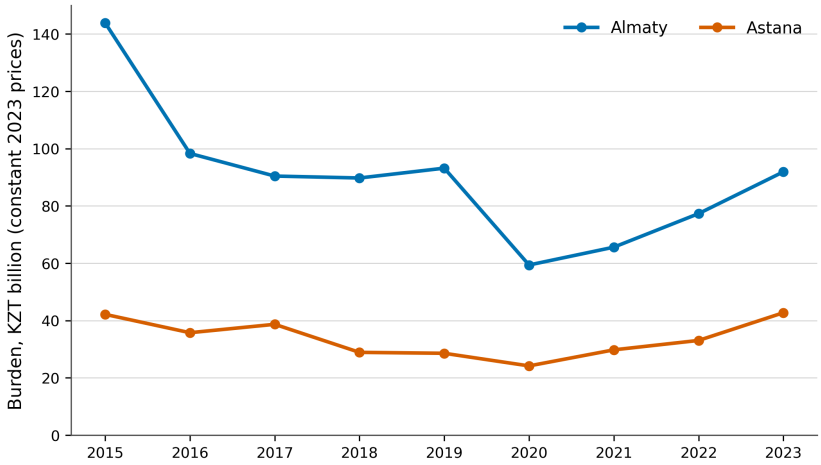


Figure 1. Annual monetized burden of registered fatalities and injuries in Almaty and Astana for 2015–2023

In Almaty, the indicator decreased from 143.87 billion tenge in 2015 to 59.39 billion tenge in 2020, after which it increased to 91.90 billion tenge in 2023. Despite the subsequent increase, the value of 2023 remained below the level of 2015. In Astana, the monetized burden decreased from 42.17 billion tenge in 2015 to 24.18 billion tenge in 2020, and then increased to 42.73 billion tenge in 2023, almost

returning to the initial level. Throughout the study period, the absolute monetized burden in Almaty remained higher than in Astana.

Table 4 reports the components of the cumulative baseline burden over the full period.

Table 4. Cumulative baseline burden for 2015–2023

City	Mortality, KZT billion	Hospitalized injuries, KZT billion	Other injuries, KZT billion	Total, KZT billion	Cumulative burden / cumulative GRP
Almaty	390.27	289.36	130.12	809.75	0.439%
Astana	119.62	176.79	7.47	303.88	0.305%
Two cities	509.89	466.15	137.59	1,113.63	–

Note: compiled by the author

From 2015 through 2023, the baseline monetized burden reached KZT 809.75 billion in Almaty and KZT 303.88 billion in Astana, a ratio of 2.66. Mortality was the largest component in Almaty, accounting for 48.2% of the total; hospitalized injuries contributed 35.7%, and other injuries 16.1%. Astana had a different composition: hospitalized injuries accounted for 58.2%, mortality for 39.4%, and other injuries for only 2.5%. This contrast follows directly from Astana's high administratively recorded hospitalization share; the data support administrative interpretation, while clinical severity remains unresolved.

Table 5 summarizes the scenario analysis and structural checks.

Table 5. Parameter sensitivity and structural checks

Scenario / check	Almaty, KZT billion	Astana, KZT billion	Total, KZT billion	Almaty / Astana	Change from baseline model
Low scenario	571.45	205.14	776.58	2.79	−30.3%
Baseline scenario	809.75	303.88	1,113.63	2.66	0.0%
High scenario	1,160.10	429.98	1,590.08	2.70	+42.8%
International VSL transfer function	833.84	312.92	1,146.76	2.66	+3.0%
Baseline model, 2016–2023	665.89	261.71	927.60	2.54	−16.7%
Common national hospitalization share	1,463.12	267.55	1,730.67	5.47	+55.4%
Mortality only	390.27	119.62	509.89	3.26	−54.2%

Note: compiled by the author

The integrated scenarios produce a combined burden ranging from KZT 776.58 billion in the low scenario to KZT 1,590.08 billion in the high scenario. Across all three scenarios, the estimated burden in Almaty remains approximately 2.7 times that in Astana. The international VSL transfer function yields a combined estimate of KZT 1,146.76 billion, which is 3.0% above the baseline estimate.

One-at-a-time sensitivity checks indicate that the 2012 VSL input has the largest effect among the individual valuation parameters. Replacing the baseline VSL with

its low or high value changes the combined estimate by −18.8% and +18.8%, respectively. Changing the hospitalized-injury weight from 13% to 10% or 16% changes the estimate by approximately −9.7% and +9.7%. Varying the income elasticity from 1.0 to 1.4 changes the combined estimate by −3.6% to +3.7%. Changes in the weight assigned to other injuries have a smaller effect: reducing the weight to 0.9% decreases the estimate by 1.2%, whereas increasing it to 1.5% raises the estimate by 6.2%.

Excluding 2015 reduces the cumulative burden by 16.7%, while the Almaty-to-Astana ratio changes only from 2.66 to 2.54. Standardizing hospitalization shares produces the largest change among the structural checks. Applying the common annual national hospitalization share increases the estimated burden in Almaty to KZT 1,463.12 billion and reduces the estimate for Astana to KZT 267.55 billion. Consequently, the Almaty-to-Astana ratio increases from 2.66 to 5.47, while the ranking of the two cities remains unchanged.

Table 6 presents the results of the Shapley decomposition using 2015 and 2016 as alternative base years.

Table 6. Endpoint sensitivity of the Shapley decomposition

City	Base period	Change in VSL	Change in Q	VSL effect, KZT billion	Registered-outcomes effect, KZT billion	Total change, KZT billion
Almaty	2015–2023	+23.9%	−48.5%	+26.08	−78.05	−51.97
Almaty	2016–2023	+31.4%	−28.9%	+26.41	−32.82	−6.41
Astana	2015–2023	+23.9%	−18.2%	+9.17	−8.60	+0.57
Astana	2016–2023	+31.4%	−9.1%	+10.72	−3.75	+6.97

Q denotes equivalent registered casualties, with weights of 1.00 for a fatality, 0.13 for a hospitalized casualty, and 0.01 for another injured person. The two Shapley components sum to the total change, apart from numerical rounding

Note: compiled by the author

With 2015 as the base year, Almaty's Q decreased from 449.71 to 231.80, corresponding to a 48.5% decline. The registered-outcomes effect was KZT −78.05 billion, while the VSL effect was KZT +26.08 billion, resulting in a total decline of KZT 51.97 billion. In Astana, the registered-outcomes effect of KZT −8.60 billion was almost fully offset by the VSL effect of KZT +9.17 billion, resulting in a small net increase of KZT 0.57 billion.

Using 2016 as the base year produces smaller registered-outcomes effects in both cities. In Almaty, Q decreased from 325.83 to 231.80, and the registered-outcomes effect fell in magnitude to KZT −32.82 billion. Combined with a VSL effect of KZT +26.41 billion, this resulted in a total decline of KZT 6.41 billion. In Astana, Q decreased from 118.53 to 107.79. The registered-outcomes effect was KZT −3.75 billion, while the VSL effect was KZT +10.72 billion, resulting in a net increase of KZT 6.97 billion.

The registered-outcomes effect is negative for both cities under both base-year specifications, while the VSL effect is positive. However, the magnitude of the registered-outcomes effect differs considerably depending on whether 2015 or

2016 is used as the base year.

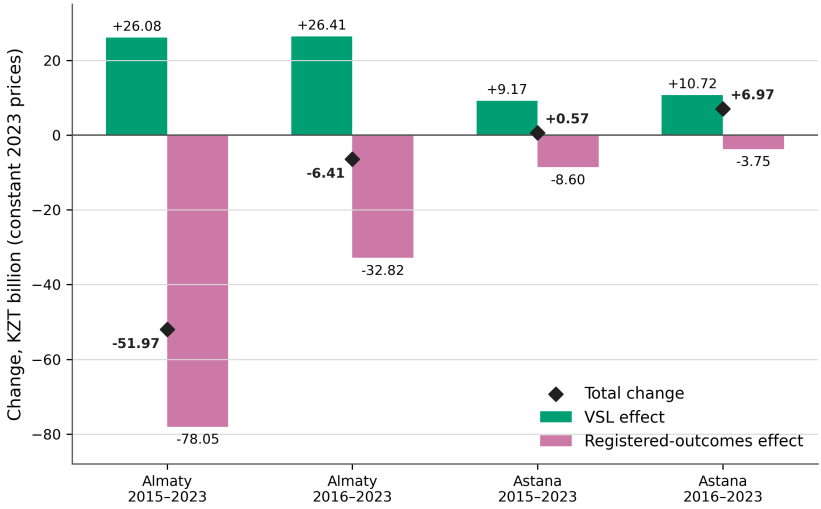


Figure 2. Sensitivity of the Shapley decomposition to the choice of base year

The mortality-only estimate is KZT 509.89 billion, 54.2% below the full baseline model. Omitting injuries would materially understate the burden, particularly in Astana, where hospitalized casualties contribute more than half of the estimate. Overall, the checks confirm substantial losses, Almaty's higher absolute and relative burden, and declining per capita indicators in both cities. Exact cross-city ratios still require caution because hospitalization practices differ, injuries may be underreported, and GRP is deflated using the national CPI.

5 | DISCUSSION

The principal finding extends beyond the higher monetized burden estimated for Almaty: the difference between the two cities persists after normalization by population and GRP and across the parameter and structural robustness checks. Because the same national VSL is applied to both cities in each year, the cross-city difference reflects the number and administratively recorded composition of casualties, summarized by the weighted casualty indicator Q, rather than differences in the monetary value assigned to risk reduction. This accounting relationship does not imply causality. The available data cannot determine whether the observed differences are associated with traffic exposure, speed, road design, enforcement, modal composition, emergency care, or other urban characteristics.

The Shapley decomposition further demonstrates the importance of the choice of base year. With 2015 as the base year, the registered-outcomes effect dominates the valuation effect in Almaty and is almost offset by the valuation effect in Astana. When 2016 is used as the base year, Almaty's total decline decreases to KZT 6.41 billion, while in Astana the positive VSL effect exceeds the negative registered-outcomes effect, resulting in a KZT 6.97 billion increase. Although

the registered-outcomes effect remains negative in both cities under both specifications, its magnitude is sensitive to the choice of base year. The anomalous hospitalization share observed in Almaty in 2015 therefore cautions against interpreting the full 2015-based decline as a pure improvement in road safety. Similarly, the minimum burden observed in 2020 cannot be causally attributed to pandemic-related mobility restrictions.

The cross-city ranking is more robust than the estimated magnitude of the difference. Almaty retains the higher burden under the low, baseline, and high valuation scenarios, after exclusion of 2015, in the mortality-only calculation, and after normalization by population and GRP. However, applying a common national hospitalization share increases the Almaty-to-Astana ratio from 2.66 to 5.47, indicating that administrative classification substantially affects the estimated size of the difference. The evidence therefore supports the conclusion that Almaty has the larger registered welfare burden, while a precise clinical or causal interpretation of the cross-city gap is not supported by the available data. Until police and medical records are more closely harmonized, the mortality component provides a more directly comparable indicator than the composition of nonfatal injuries.

Comparisons with previous studies require careful consideration of differences in scope. Wijnen (2021) estimated the total national social cost of road crashes at 3.3% of GDP, including property damage, production losses, medical costs, and administrative costs, whereas the World Bank (2022) examined health-system and household costs associated with road traffic injuries in Central Asia. In contrast, the present study estimates registered human welfare losses, with cumulative burden-to-GRP ratios of 0.439% in Almaty and 0.305% in Astana. The lower ratios are consistent with the narrower scope of the present analysis, although the estimates are not directly comparable across studies. The substantial contribution of fatalities and hospitalized casualties is also consistent with previous evidence showing that human losses account for a major share of welfare-based road crash costs (Bougna et al., 2022; Wijnen & Stipdonk, 2016; Wijnen et al., 2019).

Applying a common national VSL to both cities provides a consistent basis for comparison by assigning the same monetary value to an equivalent reduction in mortality risk. However, local preferences and willingness to pay may differ and can only be assessed through city-specific WTP studies. Accordingly, the results indicate the relative scale of registered welfare losses rather than a direct priority ranking for public expenditure. Decisions on specific road-safety interventions additionally require evidence on expected reductions in fatalities and injuries, implementation costs, feasibility, and the distribution of benefits.

6 | LIMITATIONS

The study has several limitations. First, hospitalization is an administrative proxy for injury severity and is not clinically harmonized with the MAIS3+ classification. Differences in hospitalization practices between Almaty and Astana may therefore affect the estimated composition and magnitude of the nonfatal injury burden. Second, the analysis is based on registered casualties. Nonfatal injuries may be

underreported, while city-, year-, and severity-specific correction factors are unavailable. Third, the valuation results depend on the initial WTP estimate and assumptions regarding income elasticity and injury weights. Finally, the dataset contains only 18 city-year observations and does not include measures of traffic exposure, speed, infrastructure, or enforcement. Consequently, the analysis is descriptive and does not support causal estimates of the effects of specific road-safety policies.

7 | CONCLUSION

The study estimated the monetized welfare burden associated with registered road crash fatalities and injuries in Almaty and Astana during 2015–2023. Under the baseline specification, the cumulative burden amounted to KZT 809.75 billion in Almaty and KZT 303.88 billion in Astana, or approximately KZT 1.114 trillion across the two cities. Almaty had a higher estimated burden not only in absolute terms but also per capita and relative to gross regional product. These estimates represent welfare losses associated with registered casualties and should not be interpreted as direct reductions in economic output or public budgets.

The results are robust to alternative valuation assumptions. Across the low, baseline, and high scenarios, the combined burden ranges from KZT 776.58 billion to KZT 1,590.08 billion, while Almaty consistently remains above Astana. Excluding 2015 changes the Almaty-to-Astana ratio only moderately, from 2.66 to 2.54. However, standardizing hospitalization shares increases the ratio to 5.47, indicating that the magnitude of the cross-city difference is sensitive to administrative classification of nonfatal injuries. Thus, the cross-city ordering is more robust than the estimated size of the gap.

The Shapley decomposition further shows that changes in the monetized burden reflect both changes in registered casualties and changes in the real VSL. The registered-outcomes effect is negative in both cities under both base-year specifications, while the VSL effect is positive. However, the magnitude of these effects is sensitive to whether 2015 or 2016 is used as the base year. In particular, the anomalous hospitalization share observed in Almaty in 2015 substantially affects the estimated temporal change and therefore does not support interpreting the full 2015-based decline as a direct improvement in underlying road safety.

The estimates can serve as monetary benchmarks for the cost-benefit analysis of road-safety interventions when expected reductions in fatalities and injuries and full implementation costs are available. The most robust comparative findings are Almaty's higher registered welfare burden and the mortality component, which is less sensitive to differences in hospitalization practices. Future research should prioritize linkage of police and medical records, clinically harmonized measures of injury severity, city-specific estimates of underreporting, transport-exposure indicators, and local willingness-to-pay studies.

AUTHOR CONTRIBUTIONS

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APPENDIX A. INPUT DATA USED IN THE CALCULATIONS

Panel A. Registered casualty inputs

Year	Almaty fatalities	Almaty injured	Almaty hospitalized	Astana fatalities	Astana injured	Astana hospitalized
2015	159	6,559	1,876	57	761	560
2016	156	6,231	896	42	777	573
2017	136	6,059	722	60	624	458
2018	133	5,352	684	34	559	391
2019	144	4,387	628	28	546	394
2020	84	3,807	419	31	521	283
2021	84	3,759	492	35	595	342
2022	96	4,364	475	28	750	405
2023	142	4,012	414	35	907	531

Note: compiled by the author

Panel B. Valuation and normalization inputs

Year	Baseline VSL, KZT million	Almaty population	Almaty GRP, KZT billion	Astana population	Astana GRP, KZT billion
2015	319.907	1,676,792	18,992.46	869,021	10,038.11
2016	301.723	1,731,687	19,347.39	928,965	8,879.17
2017	319.257	1,781,272	20,201.53	1,007,961	9,810.32
2018	334.146	1,832,948	19,411.73	1,060,809	10,729.31
2019	353.996	1,890,394	20,577.08	1,113,591	11,900.67
2020	344.601	1,951,746	19,157.65	1,166,590	11,351.41
2021	363.228	2,005,788	19,760.87	1,218,389	11,755.97
2022	393.212	2,131,693	21,937.22	1,325,135	12,222.93
2023	396.445	2,195,288	25,229.71	1,392,332	12,960.84

Note: compiled by the author

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Leadership and Financial Performance in Indonesian Micro, Small, and Medium-Sized Enterprises

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Abstract
In resource-constrained settings, the sustainability of micro, small, and medium-sized enterprises largely depends on how effectively managerial practices are translated into marketing capabilities, market outcomes, and financial performance. This study aims to examine whether integrated marketing communication, campaign effectiveness, and brand market performance sequentially mediate the relationship between leadership styles and financial performance. A quantitative cross-sectional research design was employed, and data collected from 398 owners, founders, and marketing managers of Indonesian MSMEs were analyzed using partial least squares structural equation modeling in WarpPLS. Transactional leadership is positively and significantly associated with integrated marketing communication ($\beta = 0.660$; $t = 9.486$; $p < 0.001$), whereas the association between transformational leadership and integrated marketing communication is not statistically significant ($\beta = 0.080$; $t = 1.038$; $p = 0.150$). The model explains the variance in integrated marketing communication ($R^2 = 0.433$), campaign effectiveness ($R^2 = 0.714$), brand market performance ($R^2 = 0.803$), and financial performance ($R^2 = 0.336$). Integrated marketing communication has no statistically significant direct association with financial performance ($\beta = -0.070$; $p = 0.180$), while campaign effectiveness ($\beta = -0.280$; $p < 0.001$) and brand market performance ($\beta = -0.330$; $p < 0.001$) are negatively associated with financial performance. Overall, the findings indicate that transactional leadership is a more important antecedent of integrated marketing communication than transformational leadership and that improvements in marketing and brand outcomes do not necessarily translate into immediate gains in financial performance among Indonesian MSMEs.

KEYWORDS
Business, Business Economics, Leadership, Transformational Leadership, Marketing Communication, Brand Performance, Indonesia

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1 | INTRODUCTION

In the current volatile, uncertain, complex, and ambiguous (VUCA) global business environment, achieving sustainable financial performance is the ultimate benchmark for organizational survival and growth (Ametefe et al., 2025). Academic literature and corporate boards alike continuously debate which strategic levers are most critical in driving firm profitability. This debate is particularly fierce within the context of Small and Medium Enterprises (SMEs) in emerging economies such as Indonesia. Indonesian SMEs serve as the backbone of the national economy, accounting for over 99% of all businesses and contributing more than 60% to gross domestic product (GDP). However, despite their macroeconomic importance, Indonesian SMEs suffer from exceptionally high vulnerability, often plagued by severe resource constraints, fierce local competition, low digital adoption, and a lack of long-term strategic planning (Oktrivina et al., 2025). Consequently, exploring how these enterprises can build resilience and secure sustainable financial performance (FP) is a matter of critical socio-economic urgency.

Dynamic capabilities theory suggests that an enterprise's financial triumph is rarely the result of a single isolated factor (Mishra et al., 2026). Instead, it stems from a complex, synchronized chain in which managerial capabilities effectively shape operational execution, which in turn optimizes market outcomes, ultimately yielding financial returns. For Indonesian SMEs, this internal synchronization begins with owner-manager leadership behavior. Two paradigms dominantly dictate how these small businesses operate: transformational leadership (TFL) and transactional leadership (TSL). Transformational leaders in SMEs inspire innovation, break traditional mindsets, and drive digital or strategic pivots (Kittikunchotiwut, 2020). Conversely, transactional leaders focus on strict budget compliance, immediate rewards for targets, and operational discipline. While the impacts of these leadership styles on employee commitment or day-to-day operations have been documented (Islam et al., 2024), their direct mechanism of translation into an SME's bottom-line financial success remains an empirical "black box". An SME owner cannot simply demand higher profits without adjusting the firm's strategic market-facing mechanisms. Therefore, exploring the intervening operational pathways that link leadership behaviors to financial outcomes is of paramount importance.

Integrated Marketing Communication (IMC) represents one of the most vital strategic mechanisms that SME leadership must mobilize to achieve market relevance (Sharma et al., 2024). IMC involves the alignment, synchronization, and optimization of all marketing communication channels such as social media, direct selling, and local promotions to deliver a clear, consistent, and competitive brand message. In Indonesia, many SMEs execute fragmented, ad hoc marketing campaigns that drain their limited capital without yielding results. Setting up a successful, cohesive IMC framework requires strong leadership vision and a commitment of resources (Yuliani et al., 2025). Once deployed by visionary leadership, an optimized IMC strategy is expected to drive two critical market-level outcomes: campaign effectiveness (CE) and brand market performance (BMP) (Luxton et al.,

2015). Campaign effectiveness captures the immediate customer engagement and sales conversions from marketing initiatives, whereas brand market performance reflects the long-term customer loyalty and local brand equity that an SME commands. Logically, these heightened market outcomes should eventually manifest as superior firm financial performance (Doja et al., 2026).

Despite these theoretical linkages, a significant gap persists in the existing literature. Most empirical studies evaluate the relationships between leadership, IMC, brand equity, and financial performance through isolated, fragmented lenses, usually focusing exclusively on large corporations or multinational firms. There is a distinct lack of empirical evidence exploring the sequential mediating pathways mapping out how transformational and transactional leadership styles flow through IMC, branch into immediate campaign effectiveness and long-term brand performance, and ultimately culminate in financial profit within the resource-constrained environment of Indonesian SMEs. Understanding this sequential chain is vital, as it explains the precise operational trajectory through which an SME owner's managerial vision converts into concrete financial survival and profitability.

To address this theoretical and empirical gap, the study examines the direct and indirect relationships between transformational and transactional leadership and the financial performance of Indonesian micro, small, and medium-sized enterprises. Particular attention is given to the sequential mediating roles of integrated marketing communication, campaign effectiveness, and brand market performance. The proposed structural model is tested using partial least squares structural equation modeling and survey data collected from enterprise owners and marketing managers in selected regions of Indonesia. The study contributes to the literature by examining how leadership-related practices are associated with marketing capabilities, market outcomes, and financial performance in resource-constrained enterprises. The study aims to test whether integrated marketing communication, campaign effectiveness, and brand market performance sequentially mediate the relationship between leadership style and financial performance.

2 | LITERATURE REVIEW

This study is grounded in dynamic capabilities theory (DCT), which builds on the resource-based view (RBV) by shifting attention from the possession of resources to the ability to reconfigure them in response to environmental change (Dukhaykh & Alangri, 2026). The RBV posits that competitive advantage stems from valuable, rare, inimitable, and non-substitutable resources, whereas DCT emphasizes that static resources alone may be insufficient in rapidly changing markets (Nugraha et al., 2026). Dynamic capabilities refer to an organization's ability to integrate, build, and reconfigure internal and external competencies in response to changing environmental conditions (Dukhaykh & Alangri, 2026). Compared with large corporations, SMEs generally possess fewer financial resources and less institutionalized organizational structures, which increases their exposure to market turbulence (Mongkol, 2022). Consequently, SMEs often de-

pend on the strategic agility, cognitive flexibility, and timely decision-making of their owner-managers to identify market opportunities and reconfigure limited resources effectively (Mongkol, 2022).

Within the proposed framework, TFL and TSL are conceptualized as managerial microfoundations that shape how SMEs identify environmental changes, evaluate market opportunities, and initiate resource reconfiguration (Dukhaykh & Alangri, 2026; Nugraha et al., 2026). IMC is treated as a dynamic marketing capability through which SMEs coordinate previously fragmented promotional activities and deliver consistent messages across communication channels (Luxton et al., 2015). Through improved communication coordination, IMC is expected to enhance CE and BMP (Luxton et al., 2015). These market outcomes may subsequently be associated with FP, thereby forming the proposed sequential mechanism linking leadership, marketing capability, market outcomes, and financial outcomes (Doja et al., 2026).

TFL motivates employees by aligning their values with the organization's strategic vision, encouraging intellectual stimulation, and fostering innovation. Within SMEs, owner-managers who exhibit transformational behaviors may promote strategic alignment by fostering collaboration and establishing a shared organizational direction. Previous research indicates that TFL can strengthen organizational innovation and capability development by creating a supportive environment for change and knowledge sharing (Hutagalung, 2026). Implementing IMC requires cross-functional coordination, consistent communication, and a unified strategic focus. Therefore, leaders who communicate a coherent brand vision and encourage collaboration may facilitate the implementation of IMC. Based on these arguments, the following hypothesis is proposed:

H1a: TFL is positively associated with IMC.

TSL emphasizes contingent rewards, compliance with established objectives, performance monitoring, and management by exception. These leadership practices can clarify employee responsibilities, performance expectations, communication standards, and budget limitations. Such operational discipline may be particularly important for resource-constrained SMEs, as it can reduce fragmentation and inefficient allocation of limited marketing resources. Previous research suggests that structured and performance-oriented leadership practices can improve operational coordination and task execution (Samodien et al., 2024). Because IMC requires consistent implementation across online and offline communication channels, the monitoring and procedural control associated with TSL may support its effective implementation. Based on these arguments, the following hypothesis is proposed:

H1b: TSL is positively associated with IMC.

IMC represents a dynamic marketing capability that enables firms to coordinate promotional activities and deliver consistent messages across communication channels (Luxton et al., 2015). An IMC system characterized by message consistency and a stakeholder-oriented strategic focus can help SMEs communicate a unified value proposition to their target audiences. Greater communication

consistency may reduce customer confusion, strengthen message recognition, and improve audience engagement. Previous research suggests that coordinating digital marketing activities and communication channels can improve customer responsiveness and marketing outcomes (Mou, 2024). Accordingly, IMC is expected to contribute positively to CE. Based on these arguments, the following hypothesis is proposed:

H2a: IMC is positively associated with CE.

Beyond its contribution to campaign outcomes, IMC may also support brand development by reinforcing a consistent brand identity across customer touchpoints (Luxton et al., 2015). BMP reflects market-related outcomes such as brand reputation, customer loyalty, market position, and perceived brand value. These outcomes are particularly important for SMEs because their financial and organizational constraints may limit their ability to build and maintain brand recognition. Consistent communication through social media, public relations, direct sales, and other channels can strengthen customer perceptions of a firm's reliability and professionalism. Previous research indicates that strategic communication consistency and stakeholder orientation can contribute to brand trust, brand equity, and market performance (Javeed et al., 2026). Therefore, IMC is expected to be positively associated with BMP. Based on these arguments, the following hypothesis is proposed:

H2b: IMC is positively associated with BMP.

From the perspective of DCT, market capabilities should ultimately translate into tangible financial prosperity. An optimized IMC framework can theoretically impact FP through two primary avenues: revenue generation and cost efficiency. By establishing streamlined internal processes and cross-channel synergy, an enterprise eliminates redundant advertising expenditures, reduces agency dependencies, and prevents conflicting promotional waste. Simultaneously, the clear messaging generated by IMC drives cross-selling and up-selling opportunities, expanding the SME's profit margins and overall cash flow.

Empirical validations of this direct link in international business journals show nuanced results, with many scholars proving that sophisticated marketing capabilities directly predict firm profitability (Javeed et al., 2026). Recent market investigations indicate that higher levels of marketing capability integration are positively correlated with return on assets (ROA) and profit margin growth. In the SME sector, the financial returns of integration often stem from operational cost savings and the capacity to command premium pricing due to superior communication clarity. However, because marketing investments often operate through intermediate market-level reactions, this direct relationship requires robust empirical validation within emerging-market frameworks. Therefore, it is hypothesized:

H2c: Integrated Marketing Communication (IMC) has a positive effect on Financial PFP.

CE reflects customers' responses to promotional activities, including engagement, purchase intention, and sales-related outcomes. Although individual campaigns are generally short-term, repeated positive campaign experiences may

strengthen customers' awareness, perceptions, and evaluation of a brand. Effective marketing activities can contribute to brand awareness, brand image, customer retention, and repurchase intention (Yang et al., 2022). The cumulative effect of successful campaigns may therefore strengthen brand reputation, customer loyalty, and market position. Based on these arguments, the following hypothesis is proposed:

H3: CE is positively associated with BMP.

CE may also be associated with FP because successful campaigns can stimulate customer demand, increase sales, accelerate inventory turnover, and generate cash inflows. These outcomes are particularly important for resource-constrained SMEs because sales revenue and liquidity are necessary for maintaining regular business operations. However, a campaign's financial contribution may depend on its implementation costs, conversion rate, and the profit margin from additional sales. Previous research suggests that effective promotional activities can improve sales-related outcomes, although their contribution to profitability may vary according to campaign expenditure and market conditions (Palma et al., 2026). Nevertheless, the potential revenue-generating effect of successful campaigns provides the basis for the following hypothesis:

H4: CE is positively associated with FP.

BMP may contribute to FP through brand reputation, customer loyalty, market share, and pricing power. A strong market position can support customer retention, reduce customer acquisition costs, and allow a firm to charge price premiums. These mechanisms may improve revenue stability and profitability. Previous research indicates that brand-related market assets can be positively associated with financial outcomes and firm value (Javeed et al., 2026). In the context of SMEs, a trusted brand may also help maintain customer demand under competitive and economic pressure. Based on these arguments, the following hypothesis is proposed:

H5: BMP is positively associated with FP.

DCT suggests that leadership may influence organizational outcomes indirectly through the development and deployment of organizational capabilities rather than through a direct transformation of managerial behavior into financial results (Dukhaykh & Alangri, 2026; Nugraha et al., 2026). Within the proposed model, TFL is treated as a managerial antecedent that may facilitate the development of IMC by encouraging strategic alignment, collaboration, and resource reconfiguration (Hutagalung, 2026). IMC may subsequently contribute to CE and BMP by improving the coordination and consistency of marketing communication activities (Luxton et al., 2015; Mou, 2024). These market outcomes may, in turn, be associated with FP, thereby creating several indirect pathways between TFL and FP (Javeed et al., 2026; Palma et al., 2026).

Research applying structural equation modeling emphasizes the importance of examining multistage indirect relationships in which organizational capabilities connect managerial practices to market and financial outcomes (Kelvin & Solomon, 2026). In the proposed model, IMC functions as the initial mediator, while CE and

BMP represent subsequent market-level mediating mechanisms. Accordingly, the following mediation and sequential mediation hypotheses are proposed:

H6a: IMC mediates the effect of TFL on Campaign Effectiveness (CE).

H6b: IMC mediates the effect of TFL on Brand Market Performance (BMP).

H6c: IMC mediates the effect of TFL on Financial Performance (FP).

H6d: IMC and CE sequentially mediate the effect of TFL on Financial Performance (FP).

H6e: IMC and BMP sequentially mediate the effect of TFL on Financial Performance (FP).

H6f: IMC, CE, and BMP sequentially mediate the effect of TFL on Financial Performance (FP).

In parallel with the TFL pathway, TSL may influence downstream market and financial outcomes through the development and implementation of IMC. TSL emphasizes procedural compliance, performance monitoring, contingent rewards, and cost control, which may help coordinate limited organizational resources (Huynh Minh, 2026). Within SMEs, these practices can help establish clear communication procedures, allocate marketing responsibilities, and monitor adherence to communication standards. Consequently, the operational discipline associated with TSL may facilitate IMC and contribute indirectly to CE, BMP, and FP.

Previous research indicates that transactional leadership practices can support operational coordination and execution by clarifying performance expectations and reinforcing compliance with organizational procedures (Reyes et al., 2025). In the proposed model, IMC functions as the initial mechanism through which TSL may influence marketing outcomes, while CE and BMP represent subsequent mediating mechanisms. This structure implies several indirect pathways connecting TSL with market and financial outcomes. Accordingly, the following mediation and sequential mediation hypotheses are proposed:

H7a: IMC mediates the relationship between TSL and CE.

H7b: IMC mediates the relationship between TSL and BMP.

H7c: IMC mediates the relationship between TSL and FP.

H7d: IMC and CE sequentially mediate the relationship between TSL and FP.

H7e: IMC and BMP sequentially mediate the relationship between TSL and FP.

H7f: IMC, CE, and BMP sequentially mediate the relationship between TSL and FP.

The empirical model developed based on the proposed hypotheses is presented in Figure 1.

3 | RESEARCH METHODOLOGY

This study employed a quantitative explanatory design based on a cross-sectional survey. Data were collected between November 2025 and March 2026 in selected regions of Indonesia, including Greater Jakarta, West Java, Central Java, East Java, and Bali. The sample covered four economic sectors: culinary and food and beverage services (38.2%), fashion and retail (31.4%), creative services (18.6%), and light manufacturing (11.8%). The target population consisted of MSME owners,

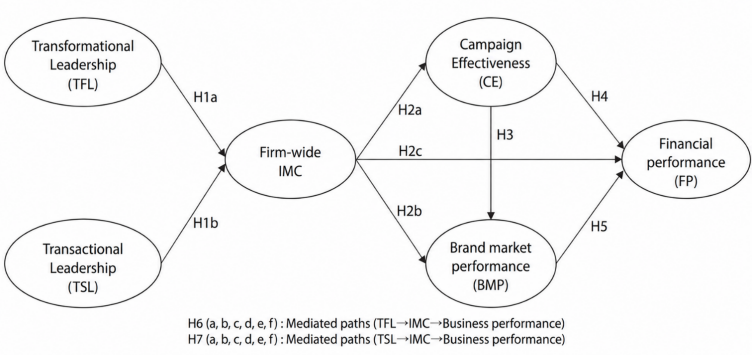


Figure 1. Proposed Model

founders, and marketing managers who participated directly in strategic marketing decisions. The focus on MSMEs was motivated by their resource constraints and dependence on owner-managers' strategic agility and capability development (Deyassa, 2023).

A non-probability purposive sampling procedure was used to recruit respondents who met predetermined eligibility criteria. Respondents were required to hold an active managerial or executive position with direct decision-making authority over strategic marketing communication. Their enterprises were also required to have operated for at least two years to provide a sufficient basis for reporting organizational and financial outcomes. A total of 550 questionnaires were distributed electronically and in paper form, of which 412 were returned, corresponding to a response rate of 74.9%. During data screening, 14 questionnaires containing more than 5% missing data were excluded. The remaining isolated missing values were imputed using the expectation-maximization algorithm.

The final analytical sample comprised 398 respondents. The demographic and professional characteristics of the respondents, as well as the distribution of their enterprises by size, are presented in Table 1.

All constructs were measured using multi-item scales adapted from previous studies. TFL and TSL were assessed using items based on the Multifactor Leadership Questionnaire (MLQ) (Pradhan & Jena, 2017). Leadership styles were assessed using MLQ, the number of items used for each leadership construct, and whether permission to use or adapt the instrument was obtained. IMC was measured as a multidimensional capability comprising message consistency, interactivity, stakeholder-oriented strategic focus, and organizational alignment (Kitchen et al., 2008; Porcu et al., 2017).

Downstream market-facing outcomes were operationalized through campaign effectiveness, which measures immediate consumer engagement and behavioral actions, and brand market performance, which assesses customer-based brand equity and relative market share. Finally, subjective financial performance was evaluated by assessing the respondents' perceptions of sales growth, profit margins, and cash flow stability relative to their key competitors over the past two fiscal years, an approach that has demonstrated high reliability and validity when objective

financial records are inaccessible in small business research (Wall et al., 2004). All items were evaluated using a five-point Likert-type scale ranging from 1 ("strongly disagree") to 5 ("strongly agree").

Table 1. Respondent Characteristic

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	238	59.8%
	Female	160	40.2%
	Total	398	100.0%
Age	< 30 years	65	16.3%
	30 - 39 years	145	36.4%
	40 - 49 years	120	30.2%
	50 years and above	68	17.1%
	Total	398	100.0%
Education Level	High School / Diploma	54	13.6%
	Bachelor's Degree	242	60.8%
	Master's Degree	88	22.1%
	Doctorate (PhD)	14	3.5%
	Total	398	100.0%
Work Experience	< 5 years	82	20.6%
	5 - 10 years	174	43.7%
	11 - 15 years	98	24.6%
	> 15 years	44	11.1%
	Total	398	100.0%
Job Position	Owner	156	39.2%
	Founder	94	23.6%
	Marketing Manager	148	37.2%
	Total	398	100.0%
Business Size (SMEs)	Micro (< 10 employees)	112	28.1%
	Small (10 - 49 employees)	198	49.7%
	Medium (50 - 249 employees)	88	22.1%
	Total	398	100.0%

Note: compiled by the authors

The empirical data were analyzed using PLS-SEM in the WarpPLS software package. PLS-SEM was selected because the model contains several latent constructs and multiple indirect pathways and focuses on explaining the variance in endogenous constructs (Hair et al., 2019; Kock, 2021). The analysis followed a two-stage procedure. First, the measurement model was evaluated using outer loadings, Cronbach's alpha, composite reliability, and average variance extracted. Discriminant validity was assessed using the Fornell–Larcker criterion and the heterotrait–monotrait ratio (Hair et al., 2019). IMC was conceptualized as a multidimensional construct encompassing message consistency, interactivity, stakeholder-

oriented strategic focus, and organizational alignment.

The second stage evaluated the structural model (inner model) to test the hypothesized relationships by estimating standardized path coefficients, calculating statistical significance via stable bootstrapping procedures, and evaluating the coefficients of determination (R2) and predictive relevance (Q2). The global fit of the overall model was verified using the Tenenhaus Goodness-of-Fit (GoF) index.

4 | RESULTS

As an initial assessment of the structural model, selected model quality and collinearity indices generated by WarpPLS were examined. These indices provide summary information on the average path estimates, explained variance across the endogenous constructs, and the potential presence of collinearity among the predictor constructs. They should be interpreted together with the construct-specific coefficients of determination, effect sizes, predictive relevance measures, and individual path estimates presented in the subsequent analyses. The results are reported in Table 2.

Table 2. Model fit and quality indices

Model Fit Indices	Output Value	Acceptance Criteria	Remarks
APC (Average Path Coefficient)	0.445 (P < 0.001)	Significant if P < 0.05	Met (Good)
ARS (Average R2)	0.548 (P < 0.001)	Significant if P < 0.05	Met (Good)
AARS (Average Adjusted R2)	0.542 (P < 0.001)	Significant if P < 0.05	Met (Good)
AVIF (Average Block VIF)	2.740	$\leq$5 (Ideally $\leq$3.3)	Met (Free from Collinearity)
Tenenhaus GoF (Goodness of Fit)	0.566	Large if $\geq$0.36	Met (Excellent)

Note: compiled by the authors

The AVIF value of 2.740 is below the recommended threshold of 3.3, indicating an acceptable average level of collinearity among the predictor constructs. The APC, ARS, and AARS values must be verified against the final WarpPLS output because they are inconsistent with the path coefficients and coefficients of determination reported in the subsequent tables. Once verified, ARS and AARS should be interpreted as summary measures of the model's average in-sample explanatory power rather than its predictive performance. The AVIF value of 2.740 is below the recommended threshold of 3.3, indicating an acceptable average level of collinearity among the predictor constructs. The explanatory power of the structural model is assessed separately for each endogenous construct using the coefficients of determination reported in Table 7. Predictive relevance is evaluated using the Q^2 values presented in Table 9, while the direction, magnitude, and statistical significance of the individual structural relationships are examined in Table 10.

To establish the quality of the measurement model, convergent validity and internal consistency reliability were systematically evaluated, with the empirical results summarized in Table 3.

Table 3. Reliability and convergent validity of first-order constructs

Latent Variable	Item	Factor Loading	AVE	CR	CA
TFL (Transformational Leadership)	TFL1	0.642	0.735	0.917	0.879
	TFL2	0.754			
	TFL3	0.747			
	TFL4	0.638			
	TFL5	0.777			
	TFL6	0.659			
	TFL7	0.846			
	TFL8	0.759			
	TFL9	0.809			
	TFL10	0.703			
	TFL11	0.627			
	TFL12	0.784			
	TFL13	0.739			
	TFL14	0.798			
	TFL15	0.786			
	TFL16	0.787			
TSL (Transactional Leadership)	TSL1	0.765	0.525	0.768	0.747
	TSL2	0.829			
	TSL3	0.688			
	TSL4	0.791			
	TSL5	0.811			
	TSL6	0.604			
	TSL7	0.639			
	TSL8	0.838			
	TSL9	0.749			
MC (Message Consistency)	MC1	0.704	0.546	0.828	0.721
	MC2	0.792			
	MC3	0.762			
	MC4	0.693			
IN (Interactivity)	IN1	0.721	0.592	0.846	0.784
	IN2	0.681			
	IN3	0.813			
	IN4	0.891			
	IN5	0.813			
	IN6	0.781			
	IN7	0.822			
SCSF (Stakeholder-centered strategic focus)	SCSF1	0.748	0.641	0.925	0.906
	SCSF2	0.857			

continued on the next page

Table 3, continued

Latent Variable	Item	Factor Loading	AVE	CR	CA
	SCSF3	0.789			
	SCSF4	0.807			
	SCSF5	0.817			
	SCSF6	0.793			
	SCSF7	0.784			
OA (Organizational alignment)	OA1	0.831	0.693	0.941	0.925
	OA2	0.879			
	OA3	0.878			
	OA4	0.803			
	OA5	0.783			
	OA6	0.771			
	OA7	0.873			
CE (Campaign effectiveness)	CE1	0.874	0.755	0.925	0.891
	CE2	0.894			
	CE3	0.875			
	CE4	0.831			
BMP (Brand market performance)	BMP1	0.803	0.676	0.936	0.921
	BMP2	0.822			
	BMP3	0.835			
	BMP4	0.845			
	BMP5	0.745			
	BMP6	0.852			
	BMP7	0.849			
FP (Financial performance)	FP1	0.615	0.585	0.752	0.778
	FP2	0.718			
	FP3	0.749			
	FP4	0.705			
	FP5	0.692			

Note: compiled by the authors

Convergent validity was assessed using the outer loadings and AVE values presented in Table 3. Outer loadings should ideally exceed 0.70, while AVE values should be at least 0.50 (Hair et al., 2019). As shown in Table 3, the outer loadings ranged from 0.604 to 0.894, with most indicators exceeding the recommended threshold of 0.70. Several indicators – TFL1 (0.642), TFL4 (0.638), TFL6 (0.659), TFL11 (0.627), TSL3 (0.688), TSL6 (0.604), TSL7 (0.639), MC4 (0.693), IN2 (0.681), FP1 (0.615), and FP5 (0.692)—had loadings between 0.60 and 0.70. These indicators were retained because the corresponding constructs met the recommended thresholds for AVE and CR. The reported AVE values ranged from 0.525 for TSL to 0.755 for CE, indicating satisfactory convergent validity for the nine first-order

constructs.

Internal consistency reliability was assessed using CR and Cronbach's alpha, for which values of at least 0.70 are generally considered acceptable (Hair et al., 2019). As reported in Table 3, the CR values ranged from 0.752 for FP to 0.941 for OA, while Cronbach's alpha values ranged from 0.721 to 0.925. Thus, all first-order constructs met the recommended internal consistency thresholds. Discriminant validity was subsequently assessed using the Fornell–Larcker criterion, as presented in Table 4.

Table 4. Fornell-Larcker criterion

Construct	CE	SCSF	MC	TAL	TSL	BMP	IN	OA	FP
CE (Campaign effectiveness)	0.869	-	-	-	-	-	-	-	-
SCSF (Stakeholder-centered strategic focus)	0.549	0.801	-	-	-	-	-	-	-
MC (Message Consistency)	0.408	0.687	0.739	-	-	-	-	-	-
TSL (Transactional Leadership)	0.381	0.544	0.601	0.725	-	-	-	-	-
TFL (Transformational Leadership)	0.343	0.508	0.560	0.685	0.857	-	-	-	-
BMP (Brand market performance)	0.680	0.537	0.458	0.363	0.344	0.822	-	-	-
IN (Interactivity)	0.618	0.702	0.607	0.483	0.441	0.501	0.769	-	-
OA (Organizational alignment)	0.564	0.757	0.626	0.596	0.560	0.534	0.698	0.832	-
FP (Financial performance)	0.426	0.335	0.275	0.248	0.191	0.513	0.347	0.403	0.765

Note: compiled by the authors

Discriminant validity at the first-order level was assessed using the Fornell–Larcker criterion. According to this criterion, the square root of AVE for each construct should exceed its correlations with all other constructs (Hair et al., 2022). As presented in Table 4, the diagonal values represent the square roots of AVE, while the off-diagonal values represent the interconstruct correlations. The diagonal values range from 0.725 for TSL to 0.869 for CE, and each diagonal value exceeds the corresponding correlations in its row and column. These results support the discriminant validity of the nine first-order constructs according to the Fornell-Larcker criterion.

Following the assessment of the first-order constructs, the internal consistency reliability of the higher-order IMC construct was evaluated using composite reliability and Cronbach's alpha. As presented in Table 5, both coefficients exceeded the recommended threshold of 0.70, supporting the reliability of the higher-order construct.

Values of composite reliability and Cronbach's alpha above 0.70 indicate acceptable internal consistency reliability (Hair et al., 2019). As shown in Table 5, the higher-order IMC construct achieved a composite reliability of 0.878 and a Cronbach's alpha of 0.799. The remaining constructs also exceeded the recommended threshold, with composite reliability values ranging from 0.752 for FP to 0.936 for BMP and Cronbach's alpha values ranging from 0.747 for TSL to 0.921 for BMP.

These results indicate satisfactory internal consistency reliability for all constructs included in the higher-order model.

Table 5. Internal consistency reliability of constructs in the higher-order model

Latent Variable	Composite Reliability	Cronbach's Alpha
IMC (Integrated marketing communication)	0.878	0.799
CE (Campaign Effectiveness)	0.925	0.891
TSL (Transactional Leadership)	0.768	0.747
TFL (Transformational Leadership)	0.917	0.879
BMP (Brand market performance)	0.936	0.921
FP (Financial performance)	0.752	0.778

Note: compiled by the authors

Following the assessment of internal consistency reliability, discriminant validity at the higher-order level was evaluated using the Fornell–Larcker criterion. The results are presented in Table 6.

Table 6. Fornell-Larcker criterion (Second-Order)

Construct	AVE> 0.5	IMC	CE	TSL	TFL	BMP	FP
IMC (Integrated marketing communication)	0.669	0.818	-	-	-	-	-
CE (Campaign Effectiveness)	0.755	0.617	0.869	-	-	-	-
TSL (Transactional Leadership)	0.525	0.546	0.382	0.725	-	-	-
TFL (Transformational Leadership)	0.735	0.592	0.343	0.698	0.857	-	-
BMP (Brand market performance)	0.676	0.795	0.682	0.364	0.344	0.822	-
FP (Financial performance)	0.585	0.393	0.426	0.248	0.191	0.513	0.765

Note: compiled by the authors

As shown in Table 6, the diagonal values represent the square roots of the Average Variance Extracted (AVE), while the off-diagonal values represent the correlations between the constructs. According to the Fornell–Larcker criterion, the square root of AVE for each construct should exceed its correlations with all other constructs (Hair et al., 2019). The diagonal values range from 0.725 for TSL to 0.869 for CE and exceed the corresponding correlations in their respective rows and columns. In particular, the square root of AVE for IMC (0.818) is greater than its highest correlation of 0.795 with BMP. Therefore, the results support the discriminant validity of the constructs included in the higher-order model.

Following the assessment of the measurement model, the explanatory power of the structural model was evaluated using the coefficients of determination (R^2 and adjusted R^2) for the endogenous constructs. The results are presented in Table 7.

Table 7. Explained variance of the endogenous constructs

Construct	R2	Adjusted R2
IMC (Integrated marketing communication)	0.433	0.426
CE (Campaign Effectiveness)	0.714	0.712
BMP (Brand market performance)	0.803	0.801
FP (Financial performance)	0.336	0.322

Note: compiled by the authors

The coefficients of determination were examined to assess the structural model's in-sample explanatory power. As presented in Table 7, the model explains 43.3% of the variance in IMC (R^2 = 0.433; adjusted R^2 = 0.426), 71.4% of the variance in CE (R^2 = 0.714; adjusted R^2 = 0.712), 80.3% of the variance in BMP (R^2 = 0.803; adjusted R^2 = 0.801), and 33.6% of the variance in FP (R^2 = 0.336; adjusted R^2 = 0.322). Based on the commonly applied PLS-SEM guidelines of 0.75, 0.50, and 0.25 for substantial, moderate, and weak explanatory power, respectively, the model exhibits substantial explanatory power for BMP, moderate-to-substantial explanatory power for CE, and weak-to-moderate explanatory power for IMC and FP (Hair et al., 2019). These results describe the model's in-sample explanatory power, whereas its predictive relevance is assessed separately using the Q^2 values.

In addition to the coefficients of determination, the local effect sizes (f^2) were examined to assess the incremental contribution of each predictor to the explained variance of the corresponding endogenous construct. The results are presented in Table 8.

Table 8. Effect sizes for structural paths

Construct	TFL	TSL	IMC	CE	BMP	FP
TSL (Transactional Leadership)	-	-	0.409	-	-	-
TFL (Transformational Leadership)	-	-	0.024	-	-	-
IMC (Integrated marketing communication)	-	-	-	0.714	0.712	0.241
CE (Campaign Effectiveness)	-	-	-	-	0.493	0.231
BMP (Brand market performance)	-	-	-	-	-	0.167

Note: compiled by the authors

The effect sizes of the structural paths were examined to assess the relative contribution of each predictor to the explained variance of the corresponding endogenous construct. Values of 0.02, 0.15, and 0.35 indicate small, medium, and large effect sizes, respectively (Cohen, 1988). As shown in Table 8, TSL has a large effect size on IMC (f^2 = 0.409), whereas TFL has a small effect size on IMC (f^2 = 0.024). IMC exhibits large effect sizes on CE (f^2 = 0.714) and BMP (f^2 = 0.712), while CE has a large effect size on BMP (f^2 = 0.493). Regarding FP, IMC (f^2 = 0.241), CE (f^2 = 0.231), and BMP (f^2 = 0.167) exhibit medium effect sizes. Following the assessment of the effect sizes, the predictive relevance of the structural model was evaluated using the Stone–Geisser Q^2 values. The results are presented in Table 9.

Table 9. Predictive Relevance

Construct	Cross-validated redundancy (Q2)	Prediction capability (Redundancy)
IMC (Integrated marketing communication)	0.353	0.353
CE (Campaign Effectiveness)	0.653	0.653
BMP (Brand market performance)	0.759	0.759
FP (Financial performance)	0.278	0.278

Note: compiled by the authors

The predictive relevance of the structural model was assessed using the Stone–Geisser Q^2 values obtained through the blindfolding procedure (Hair et al., 2019; Kock, 2021). As presented in Table 9, the Q^2 values are positive for all endogenous constructs: IMC (Q^2 = 0.353), CE (Q^2 = 0.653), BMP (Q^2 = 0.759), and FP (Q^2 = 0.278). These results support the model's predictive relevance for all four endogenous constructs. The comparatively higher Q^2 values for CE and BMP indicate stronger predictive relevance for these market-related outcomes than for IMC and FP. However, the Q^2 values reflect cross-validated predictive relevance within the estimated model and should not be interpreted as evidence of out-of-sample predictive accuracy.

The statistical empirical results from the structural model analysis provide detailed insights into the direct relationships among the hypothesized constructs (Table 10).

Table 10. Structural Model Results for Direct Hypotheses

Hypothesis	Proposed Path	Path Coefficient (β)	t-value	p-value	Decision
H1a	TFL →IMC	0.080	1.038	0.150	Not supported
H1b	TSL →IMC	0.660	9.486***	< 0.001	Supported
H2a	IMC →CE	0.850	12.426***	< 0.001	Supported
H2b	IMC →BMP	0.370	12.382***	< 0.001	Supported
H2c	IMC →FP	-0.070	0.925	0.180	Not supported
H3	CE →BMP	0.564	7.78***	< 0.001	Supported
H4	CE → FP	-0.280	3.623***	< 0.001	Not supported: opposite direction
H5	BMP →FP	-0.330	4.355***	< 0.001	Not supported: opposite direction

Note: compiled by the authors

As shown in Table 10, TSL is positively and significantly associated with IMC (β = 0.660, p < 0.001), supporting H1b, whereas the relationship between TFL and IMC is not statistically significant (β = 0.080, p = 0.150); therefore, H1a is not supported. IMC is positively associated with CE (β = 0.850, p < 0.001) and BMP (β = 0.370, p < 0.001), supporting H2a and H2b. However, its direct relationship with FP is not statistically significant (β = −0.070, p = 0.180), and H2c is not supported. CE is positively associated with BMP (β = 0.564, p < 0.001), supporting H3. Although the relationships of CE (β = −0.280, p < 0.001) and BMP (β = −0.330, p < 0.001) with FP

are statistically significant, their directions are negative and therefore contrary to the positive relationships proposed in H4 and H5. Accordingly, H4 and H5 are not supported.

To uncover the mechanism through which leadership styles influence ultimate financial performance, the sequential indirect effects were systematically analyzed (Table 11).

Table 11. Results of mediation and sequential mediation tests

Hypothesis	Proposed Indirect Path	Mediation Type / Effect	Decision
H6a	TFL → IMC → CE	Weak positive indirect effect	Partially supported
H6b	TFL → IMC → BMP	Weak positive indirect effect	Partially supported
H6c	TFL → IMC → FP	Non-significant indirect effect	Not supported
H6d	TFL → IMC → CE → FP	Significant indirect effect	Supported
H6e	TFL → IMC → BMP → FP	Significant indirect effect	Supported
H6f	TFL → IMC → CE → BMP → FP	Significant sequential mediation	Supported
H7a	TSL → IMC → CE	Strong positive indirect effect	Supported
H7b	TSL → IMC → BMP	Strong positive indirect effect	Supported
H7c	TSL → IMC → FP	Non-significant indirect effect	Not Supported
H7d	TSL → IMC → CE → FP	Significant indirect effect	Supported
H7e	TSL → IMC → BMP → FP	Significant indirect effect	Supported
H7f	TSL → IMC → CE → BMP → FP	Highly significant sequential mediation	Supported (full sequential mediation)

Note: compiled by the authors

The findings confirm that financial performance cannot be directly triggered by strategic leadership alone; rather, it operates through a structured multi-stage transmission process.

For transformational leadership, indirect paths H6a and H6b exhibit weak mediation effects, while H6c is not supported due to the non-significant direct relationship between IMC and FP. However, when marketing effectiveness metrics are incorporated sequentially, H6d, H6e, and notably H6f (TFL→IMC→CE→BMP→FP) are fully supported. This validates the presence of a full sequential mediation chain, demonstrating that transformational vision requires operational execution (IMC), campaign execution (CE), and brand consolidation (BMP) to eventually impact financial outcomes.

For transactional leadership, the sequential mediation paths demonstrate even stronger statistical significance. H7a and H7b are strongly supported, reinforcing TSL's role as an effective driver of structured marketing capabilities. While the direct indirect link through IMC to FP (H7c) remains non-significant, the complex sequential paths—H7d, H7e, and the complete chain H7f (TSL→IMC→CE→BMP→FP) — are highly significant. These results highlight that transactional leadership acts

as the primary engine for setting up structured IMC, which subsequently cascades down to campaign effectiveness, brand building, and ultimately, sustainable financial growth.

In line with DCT, TFL and TSL do not automatically translate into financial success. Rather, they require IMC to serve as an operational engine that drives downstream market success (CE and BMP), which in turn translates into FP. Intriguingly, in the resource-constrained environment of Indonesian MSMEs, TSL has a substantially greater direct impact on IMC than TFL. This underscores the critical importance of structured oversight, cost controls, and strict adherence to communication protocols over abstract creative vision in small businesses.

5 | CONCLUSION

This study examined how transformational and transactional leadership influence the financial performance of Indonesian SMEs through the sequential roles of IMC, campaign effectiveness, and brand market performance. The findings demonstrate that leadership does not translate automatically into superior financial outcomes. Instead, its influence operates through a multistage capability-building process in which leadership shapes IMC practices, IMC enhances marketing outcomes, and these outcomes, in turn, affect financial performance. Transactional leadership emerged as a strong antecedent of IMC, whereas the direct effect of transformational leadership on IMC was not statistically significant. These results indicate that, in resource-constrained SMEs, structured coordination, performance monitoring, and adherence to established communication procedures may be more consequential for IMC implementation than visionary leadership alone.

IMC was found to exert strong positive effects on both campaign effectiveness and brand market performance, while campaign effectiveness also significantly strengthened brand market performance. Nevertheless, IMC did not directly improve financial performance. Moreover, campaign effectiveness and brand market performance exhibited significant negative direct relationships with financial performance. These findings suggest that improvements in marketing and brand-related outcomes may impose short-term financial pressures, as campaign execution and brand development require substantial, sustained investment. Accordingly, stronger marketplace outcomes should not necessarily be interpreted as generating immediate profitability. The significant sequential mediation effects further indicate that the financial implications of leadership become observable only when leadership translates into coordinated communication practices, effective campaigns, and stronger brand outcomes.

Theoretically, this study extends Dynamic Capabilities Theory by identifying IMC as an important operational capability that connects managerial behavior with market and financial outcomes. It also refines the theory by demonstrating that the effectiveness of different leadership styles depends on the organizational context and the stage of capability development. In the Indonesian SME setting, transactional leadership appears particularly relevant to the implementation stage because it provides the discipline required to coordinate limited resources and

maintain consistency across communication channels. The results therefore contribute to the leadership and marketing literature by revealing a sequential mechanism through which internal managerial practices are converted into external market outcomes and, ultimately, financial consequences.

From a managerial perspective, SME owners and managers should complement strategic vision with clear responsibilities, measurable marketing objectives, budgetary controls, and consistent communication protocols. IMC should be managed as an organization-wide capability rather than as a collection of isolated promotional activities. Managers should also evaluate marketing investments using both short-term financial indicators and longer-term market indicators, including customer engagement, brand recognition, loyalty, and market position. This balanced approach is particularly important because investments that strengthen campaigns and brands may temporarily reduce profitability before their economic benefits are realized.

Several limitations provide opportunities for further research. First, the cross-sectional design does not capture the time lag between marketing investment, brand development, and financial returns; consequently, the interpretation of the negative financial coefficients as short-term cost pressures should be tested directly through longitudinal research. Second, the use of perceptual, self-reported measures may introduce common-method bias and may not fully reflect objective financial performance. Future studies should combine survey data with accounting measures such as revenue growth, operating margin, return on assets, and cash-flow performance. Third, because the sample is limited to Indonesian SMEs, caution is required when generalizing the findings to larger firms or other institutional settings. Comparative studies across countries, industries, and firm-size categories would strengthen external validity. Finally, future research could examine whether digital maturity, environmental turbulence, organizational culture, financial slack, and firm age condition the identified relationships. Addressing these limitations would provide a more comprehensive understanding of when and how leadership-enabled marketing capabilities generate sustainable financial value.

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ORIGINAL ARTICLE

Intersectoral Linkages in Kazakhstan's Energy Sector: A Comparative Leontief Analysis

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Abstract
The intensive utilization of production resources in Kazakhstan's energy sector and the increase in interdependence between industries make it particularly important to assess the stability and efficiency of the economic system structure. In particular, the coal, petroleum, natural gas and electric power industries constitute the main energy base of the national economy and reflect the interconnection between industries. Therefore, the analysis of intersectoral relationships and structural transformation in the energy sector has become the main direction of modern economic research. In addition, changes in the flow of resources within the energy system directly affect the long-term stability and efficiency of the economy. The purpose of this research is to use a comparative Leontief input-output analysis to examine changes in intersectoral relationships within Kazakhstan's energy sector and evaluate structural transformations from 2020 to 2024. The methodological basis of this research is a comparative input-output analysis based on the Leontief inter-industry equilibrium framework. This study uses the official statistics of the Republic of Kazakhstan for 2020-2024, including production indicators of the energy sector and intersectoral intermediate consumption data. The analysis is based on a reduced four-sector input-output framework representing the main energy industries of Kazakhstan (coal, oil, natural gas, and electricity), rather than the complete national input-output table. In addition, the intermediate consumption matrix (Z_t), the technical coefficient matrix (A_t), the Leontief inverse matrix ($(I - A_t)^{-1}$), and backward linkage (BL) and forward linkage (FL) indicators were calculated. The findings reveal that moderate structural adjustments occurred within Kazakhstan's energy system during 2020-2024. The electricity sector exhibited the highest multiplier effect, confirming its role as the core sector of the system. The obtained results characterize the changing production interdependencies within the energy system, the restructuring of intersectoral linkages, and the systemic evolution of the energy sector.

KEYWORDS
Energy, Energy Economy, Energy Sector, Sectoral Dependence, Resource Flow, Production Structure, Intersectoral Relationship, Leontief Model

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1 | INTRODUCTION

At present, the depletion of natural resources, the growth of industrial waste, and climate change have become among the major environmental and economic challenges threatening the sustainable development of the global economy. At the international level, these challenges require new analytical and policy approaches to improve resource efficiency, reduce carbon emissions, and manage industrial waste. In particular, the energy sector is considered one of the most resource-intensive areas of economic activity and a major contributor to environmental pressure (Karatayev et al., 2016). The industrialization of the global economy has led to increasing energy consumption, the accumulation of industrial waste, and the expansion of harmful atmospheric emissions (Steffen et al., 2015). As a result, many countries are seeking new development models that ensure resource efficiency and environmental sustainability. In this context, growing attention has been devoted to the concept of the circular economy (Kirchherr et al., 2017).

The energy sector is of strategic significance in Kazakhstan's economy and is one of the main engines of the country's industrial development. Coal, oil, natural gas, and electricity constitute the core of Kazakhstan's energy system and generate substantial export revenue. However, the sector is characterized by high resource intensity, substantial industrial waste generation, and increasing environmental impacts.

In addition to contributing to industrial production and economic growth, Kazakhstan's energy sector plays an important social role, supporting employment, household welfare, and regional development. Structural changes in the energy system can affect labor demand in related sectors, the reliability of energy supply, and the effectiveness of public investments. In addition, strengthening intersectoral linkages can help maintain national energy security and provide a more stable basis for implementing long-term economic and social policies. Therefore, analyzing the structural transformation of the energy sector is important not only for understanding its economic significance but also for assessing its implications for social development and public policy.

Until recently, economic development was mainly based on traditional linear economic principles. This model is characterized by a linear resource flow based on extraction, production, consumption, and disposal, which has contributed to resource depletion, increasing waste generation, and environmental degradation (Korhonen et al., 2018). International experience has shown that the linear economic model is insufficient to ensure long-term sustainable development. Therefore, in recent years, the concept of the circular economy has attracted widespread attention in the academic literature and public policy fields.

Intersectoral analysis methods have been widely used to comprehensively assess the environmental and economic relationships within the energy sector. The Leontief input-output framework provides a systematic approach to analysing production flows among different sectors of the economy (Leontief, 1986). It has also been widely applied to evaluate structural changes, intersectoral linkages, and multiplier effects across different time periods.

In this study, a comparative input-output analysis based on the Leontief framework is employed to examine the structural transformation of Kazakhstan's energy sector. Specifically, for Kazakhstan's energy sector from 2020 to 2024, the technical coefficient matrix (At), intermediate consumption matrix (Zt), total output vector (Xt) and Leontief inverse matrix ((I – At)-1) are calculated, and changes in these matrices are analysed.

The main advantage of this method is that it captures not only direct production linkages but also indirect multiplier effects. This allows us to determine the degree of structural dependence between the energy sectors, changes in intersectoral relationships, and the direction of economic structural adjustment. In addition, backward linkage (BL) and forward linkage (FL) indicators are used to identify the systemic role of each sector as a major user of inputs or supplier of outputs.

In Kazakhstan, the evolution of the energy sector's production structure, changes in intersectoral dependence, and the structural transformation of the energy system have not yet been comprehensively studied. In particular, studies applying comparative input-output analysis to examine structural changes and intersectoral relationships in Kazakhstan's energy sector remain limited.

The identified research gaps are addressed in this study, and several key contributions are made. First, the intersectoral structure of Kazakhstan's energy sector is analysed using comparative Leontief input-output analysis. Second, structural changes during 2020-2024 are quantified using the technical coefficient matrix and the Leontief inverse matrix. Third, the systemic roles of energy sectors are identified using backward and forward linkage indicators, thereby characterizing their relative systemic importance within the energy sector. Fourth, the results enable interpretation of changes in the energy sector's multiplier structure.

The study aims to assess changes in intersectoral linkages within Kazakhstan's energy sector during 2020–2024 using comparative Leontief input–output analysis. To achieve this objective, the following research tasks are formulated:

(1) constructs annual four-sector intermediate consumption and technical coefficient matrices;

(2) calculates and compares the corresponding Leontief inverse matrices for 2020–2024;

(3) assesses backward and forward linkages within Kazakhstan's energy subsystem.

2 | LITERATURE REVIEW

The structural transformation of energy systems has attracted growing attention because of its implications for economic efficiency, employment, industrial competitiveness, regional development, energy security, and macroeconomic stability. Changes in intersectoral production linkages may influence employment dynamics, industrial competitiveness, regional development, energy security, and overall macroeconomic stability. Therefore, the assessment of structural changes within energy systems has become an important research direction in contemporary economic studies (IEA, 2024; ILO, 2023). Understanding these transformations re-

quires analytical approaches that capture complex relationships among economic sectors, resource flows, and environmental impacts.

The theory of the circular economy has, in recent years, become one of the key directions within the concept of sustainable development and is increasingly regarded as a new economic model based on the efficient use of resources and the reduction of industrial waste (Geissdoerfer et al., 2017; Kirchherr et al., 2017). While traditional linear economic systems are based on the «take-use-dispose» principle, the goal of a circular economy is to ensure environmental sustainability through the reuse, recycling, and reintegration of recycled materials into the production cycle (Korhonen et al., 2018). In this regard, a comprehensive assessment of industrial waste generation and resource flows is particularly important in scientific research. Because the energy sector is one of the most resource-intensive industries and exerts significant environmental pressure, modeling waste flows in this sector has become a major research area in the circular economy (Karatayev et al., 2016).

The input-output framework developed by Wassily Leontief provides a fundamental analytical approach for examining intersectoral relationships within an economy (Leontief, 1986). The framework describes the flow of intermediate inputs among sectors and enables identification of the direct and indirect production requirements associated with changes in final demand. The technical coefficient matrix represents the direct input requirements of each sector, while the Leontief inverse captures the total production effects generated throughout the economy. Consequently, Leontief input-output analysis can be used to assess intersectoral dependencies, multiplier effects, and the relative importance of individual sectors within a production system (Miller & Blair, 2009). These analytical capabilities have made the Leontief framework an important tool for examining structural changes and linkages across economic sectors. Building on this framework, researchers have also developed extended input-output models incorporating environmental variables such as energy consumption, greenhouse gas emissions, and resource use, thereby broadening the application of input-output analysis to sustainability and environmental assessment.

With the development of Input-Output Analysis, the comparative application of the Leontief framework has become an important method for examining changes in the structure of production systems over time. By comparing input-output tables across different periods, researchers can identify changes in technical coefficients, intermediate input requirements, production structures, and intersectoral relationships. For example, Weber (2009) employed Input-Output Analysis and decomposition analysis to examine changes in energy use and structural transformation in the US economy between 1997 and 2002, demonstrating the importance of changes in the production structure for understanding energy demand. Similarly, Han and Lakshmanan (1994) applied energy input-output analysis to examine structural changes and energy consumption in the Japanese economy between 1975 and 1985. More recently, Nieto et al. (2022) analyzed time-series input-output tables to assess the relationship between energy intensity and changes in the process coefficient matrix, emphasizing the importance of input-output struc-

tures in analyzing long-term structural transformation. Therefore, comparative Input-Output Analysis can be used to assess changes in production technologies, intersectoral interdependencies, and the direct and indirect effects captured by the Leontief inverse matrix. This approach is particularly important for research in the energy sector because changes in the structure of production and energy demand can alter the systemic role of different subsectors within the economy as a whole.

Donati et al. (2020) developed an environmentally extended input-output framework for modeling circular economy strategies, including resource efficiency and product lifetime extension. Their study demonstrated how input-output models can be extended to assess the environmental and socio-economic effects of circular economy intervention.

Wiebe et al. (2019) applied a multi-regional input-output (MRIO) model to compare a business-as-usual scenario with a circular economy scenario, examining the economy-wide, environmental, and employment effects of increased recycling, material efficiency, repair, and reuse. Their results demonstrated the potential of MRIO analysis to assess the broader impacts of circular economy strategies.

While previous studies have extensively applied input-output models to analyse environmental impacts, resource efficiency, and circular economy strategies, limited attention has been given to the structural transformation of Kazakhstan's energy sector through comparative Leontief analysis. In particular, changes in intersectoral dependencies, production linkages, and multiplier effects among key energy subsectors remain insufficiently explored. Therefore, this study addresses this research gap by applying comparative input-output analysis to evaluate structural changes in Kazakhstan's energy sector during 2020-2024.

Recent developments in intersectoral analysis and modeling of circular economies further expand the theoretical and methodological foundations of this study. For example, Su and Ang (2010) used an intersectoral analysis method to examine carbon emissions in international trade, focusing on the impact of industrial structure on the environment.

Tukker and Dietzenbacher (2013) conducted a comprehensive review of sustainability analysis based on intersectoral balance, emphasizing the importance of linking economic structure to environmental pressures in policy assessments. Lenzen et al. (2013) proposed a high-precision multi-regional input-output database that tracks energy consumption and emissions across the global supply chain in detail, significantly improving the accuracy of environmental accounting. Zeng et al. (2017) used input-output methods to study the development of China's circular economy and identified key issues, such as waste generation and resource inefficiency, in specific industries.

Dietzenbacher et al. (2015) extended the structural decomposition method to input-output models, enabling them to analyze how changes in production structure and demand composition affect economic performance over time. Hertwich and Wood (2018) used the multi-regional input-output model (MRIO) to analyze the impact of consumption on the global environment, emphasizing the importance of the final demand structure in determining resource utilization and

emissions. Finally, Owen et al. (2018) analyzed the role of input-output analysis in energy transition research, emphasizing its usefulness in evaluating the structural aspects of the transition to a low-carbon economy. However, existing studies mainly focus on global economies or environmental assessments, while empirical evidence on structural transformations within Kazakhstan's energy sector remains limited. This study contributes to the literature by applying comparative Leontief input-output analysis to identify changes in sectoral relationships and multiplier effects during 2020-2024.

Despite the extensive application of input-output models to examine structural change, intersectoral linkages, energy use, and environmental impacts, empirical evidence on the structural transformation of Kazakhstan's energy sector remains limited. Existing studies on energy and input-output relationships have predominantly focused on environmental impacts, resource use, energy efficiency, or economy-wide assessments. At the same time, comparatively little attention has been given to changes in intersectoral production linkages within Kazakhstan's energy sector over time. In particular, the comparative analysis of technical coefficient matrices, Leontief inverse matrices, and backward and forward linkages across different periods remains insufficiently explored.

Although input–output methods have been widely applied to analyze energy use, emissions, and structural change, evidence on year-to-year changes in production linkages among Kazakhstan's coal, oil, natural gas, and electricity sectors remains limited. This study addresses this gap by comparing annual technical coefficient and Leontief inverse matrices and assessing absolute backward and forward linkage measures for 2020–2024.

3 | RESEARCH METHODS

This study uses the Leontief input-output model and comparative input-output analysis to evaluate structural changes in intersectoral linkages in Kazakhstan's energy sector. This approach enables analysis of production interdependence, resource flows, and multiplier effects across various sectors of the economy by comparing annual input-output tables.

The methodological basis of this research is the classic input-output equilibrium model proposed by Wassily Leontief. The model describes intersectoral production relationships among economic sectors in matrix form and can evaluate product flows across sectors. The main equations of the classic input-output equilibrium model are as follows (1):

$$X = AX + Y \tag{1}$$

where:

X – vector of total economic output;

A – matrix of intersectoral technical coefficients;

Y – vector of final demand.

This model shows that a portion of output is used for intermediate consumption in other sectors, while the remaining share is directed towards final consumption.

The technical coefficient matrix describes the technological interdependence between sectors and determines the degree to which each sector depends on the products of other sectors. By transforming equation (1), we obtain the standard Leontief form:

$$X = (I - A)^{-1} Y \tag{2}$$

where:

I – identity matrix;

(I – A)-1 – Leontief inverse matrix, representing the total multiplicative effect of direct and indirect production relationships.

The Leontief inverse matrix reflects the full impact of direct and indirect interdependencies in production within the economy. Each element of the matrix indicates the extent to which a change in final demand in a particular sector influences the total level of economic output.

To examine structural changes in Kazakhstan's energy sector, separate technical coefficient matrices were constructed for each year of the study period (2020-2024). Based on these matrices, the corresponding Leontief inverse matrices were constructed and analyzed to compare changes in intersectoral production relationships over time.

The gross output vector X_t for each year was constructed from the gross output of the four energy sectors: coal production, oil extraction, natural gas production, and electric power generation. The corresponding gross output values are presented in Table 1 in the Results section. For each year t, the gross output vector was defined as (3):

$$X_t = \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \\ x_4(t) \end{bmatrix} \tag{3}$$

where:

$x1$ – coal production;

$x2$ – oil production;

$x3$ – natural gas production;

$x4$ – electric power generation.

The intermediate consumption matrix for year (t) was defined as Z_t , where represents the monetary value of the output supplied by sector (i) and used as an intermediate input by sector (j). The technical coefficient matrix was calculated as (4) and (5):

$$A_t = Z_t \overline{X_t}^{-1} \tag{4}$$

$$a_{ij} = \frac{z_{ij}}{x_j} \tag{5}$$

where:

A_t – technical coefficient matrix;

Z_t – intermediate consumption matrix;

$\overline{X_t}^{-1}$ – inverse diagonal matrix of gross output;

z_{ij} – output of sector (i) used in the production process of sector (j);

x_j – gross output of sector (j).

The technical coefficient matrices (A_t) were constructed separately for each year from 2020 to 2024 using official input-output tables published by the Bureau of National Statistics of the Republic of Kazakhstan. The gross output vectors (X_t) and intermediate consumption matrices (Z_t) were obtained directly from the official input-output tables for the corresponding years. Based on these data, the technical coefficient matrices were calculated according to Equation (4), and the corresponding Leontief inverse matrices were subsequently derived for each year to enable a comparative input-output analysis of changes in intersectoral production relationships over time.

The analysis is focused on four major sectors of Kazakhstan's energy industry: coal production; oil extraction; natural gas production; electric power generation. For each year during the period 2020-2024, separate gross output vectors (X_t), intermediate consumption matrices (Z_t), technical coefficient matrices (A_t), and Leontief inverse matrices ($(I - A_t)^{-1}$) were calculated and compared.

In addition, backward linkage (BL) and forward linkage (FL) indicators were applied to evaluate the systemic role of the energy sectors. The backward linkage indicator describes the extent to which a sector draws resources from other sectors. In contrast, forward linkage indicator reflects the extent to which that sector's products are used in the broader economy.

The BL and FL metrics are determined by summing the corresponding columns and rows of the inverse Leontief matrix (6) and (7):

$$BL_j = \sum_i l_{ij} \tag{6}$$

$$FL_i = \sum_j l_{ij} \tag{7}$$

where:

l_{ij} – represents the elements of the Leontief inverse matrix.

The measures were calculated as simple column and row sums without Rasmussen–Hirschman normalization. Consequently, they are interpreted as absolute linkage measures rather than normalized linkage indices. They are used to compare the relative positions of the four sectors and their changes over time, but not to classify sectors as "key sectors" based on a normalized threshold.

This procedure provides a consistent basis for comparing changes in production interdependence and linkage structures within Kazakhstan's four-sector energy subsystem during 2020–2024.

4 | RESULTS

The empirical analysis employed a reduced four-sector input–output model comprising coal production, oil extraction, natural gas production, and electricity generation. Accordingly, the derived Leontief multipliers and linkage measures capture structural relationships within the analyzed energy subsystem rather than within Kazakhstan's economy as a whole.

The calculations based on the comparative Leontief input-output model indicate that the energy sector in Kazakhstan underwent significant structural changes during 2020-2024. The numerical data used in the analysis were compiled from official statistical sources, and changes in intersectoral relationships were assessed by comparing annual technical coefficient matrices. The technical coefficients did not exhibit a uniform downward trend. Instead, they showed considerable structural variation across sectors, with the most pronounced changes observed after 2022.

Table 1 presents the gross output values used as the empirical basis for constructing the annual input-output matrices.

Table 1. Gross output of the selected energy sectors in Kazakhstan for 2020–2024, in KZT thousand

Indicator	2020	2021	2022	2023	2024
Coal production	570 469 600	647 156 633	977 766 378	874 778 826	843 722 600
Oil production	8 168 627 300	13 179 766 639	19 278 363 928	16 037 269 765	16 382 767 200
Natural gas production	418 313 500	428 895 731	624 088 747	460 542 968	455 455 400
Electric power generation	1 464 707 199	1 883 597 343	2 311 864 715	2 385 422 844	2 660 278 399

Note: compiled by the authors

The data show substantial differences in production dynamics across the four energy sectors. Oil extraction accounted for the largest monetary gross output throughout the study period. Electricity generation was the only analyzed sector whose gross output increased every year, rising from KZT 1.465 trillion in 2020 to KZT 2.660 trillion in 2024, or by 81.6%. The monetary gross output of coal, oil, and natural gas reached its highest level in 2022. Between 2022 and 2024, it subsequently decreased by 13.7% for coal, 15.0% for oil, and 27.0% for natural gas. These changes in sectoral output provide the empirical basis for assessing changes in intersectoral production relationships during 2020-2024.

The selected intermediate consumption linkages for Kazakhstan's energy subsystem for 2020–2024 are presented in Table 2.

The results demonstrate substantial changes in the intensity of intersectoral linkages during 2020-2024. Coal-to-electricity flows remained among the largest intermediate linkages throughout the period, although their magnitude declined after 2022. Electricity-to-oil and electricity-to-gas linkages also varied considerably across the study period. In contrast, electricity-to-electricity intermediate consumption increased sharply in 2023-2024, indicating a substantial strengthening of internal production linkages within the electricity sector. Overall, the observed

changes indicate a transformation in the structure and intensity of intersectoral relationships within Kazakhstan's energy subsystem.

Table 2. Selected intermediate consumption linkages in Kazakhstan's energy subsystem for 2020- 2024

Producer sector / Consuming sector	2020	2021	2022	2023	2024
Coal→ Coal	3 884 149	3 717 841	8 423 917	21 280 997	12 801 819
Coal→ Oil	20 167	43 488	78 961	5 235	5 118
Coal→ Gas	-	-	-	240	245
Coal→ Electricity	128 988 430	139 096 529	221 446 570	173 073 419	122 022 945
Oil→ Coal	-	-	-	-	-
Oil→ Gas	-	-	-	-	-
Oil→ Oil	28 686 317	95 892 259	35 934 857	66 665 097	53 609 340
Oil→ Electricity	99 423	293 025	6 455	-	-
Gas→ Coal	-	-	-	-	-
Gas→ Oil	11 383 308	38 184 571	103 784 346	5 804 764	14 295 386
Gas→ Electricity	5 071 493	8 497 562	16 889 388	11 733 754	23 676 593
Electricity→ Coal	18 004 686	17 916 593	46 940 390	2 809 631	1 430 237
Electricity→Oil	54 873 385	107 089 841	203 773 854	75 165 787	60 791 513
Electricity→Gas	21 171 446	28 444 091	55 724 904	1 817 000	1 571 411
Electricity→Electricity	23 504 117	28 662 018	48 709 185	301 341 967	287 405 773

Note: compiled by the authors

The technical coefficient matrix (A_t) describes the technological structure of production within Kazakhstan's energy subsystem by indicating the amount of input required from each sector to produce one unit of output in another sector. The technical coefficient matrices for 2020-2024 were calculated based on the corresponding intermediate consumption and total output data.

Figure 1 illustrates the changes in the technical coefficient matrix (A_t) for the period 2020-2024 and shows how intersectoral production linkages evolved over the study period, reflecting changes in technological dependence among the energy sectors.

The results shown in Figure 1 indicate that most technical coefficients remained relatively low throughout the study period, while several coefficients demonstrated substantial structural variation. In particular, the coefficients (a14), (a41), (a43), and (a44) exhibited the most pronounced changes, indicating shifts in the intensity of key production linkages within Kazakhstan's energy subsystem.

The a14 coefficient was relatively high during 2020-2022 and increased to 0,09582 in 2022. This indicates a strengthening dependence of sector 4 (electric power generation) on intermediate inputs supplied by the coal sector (coal industry). However, the sharp decline in 2023-2024 reflects a structural change in production or an ongoing technological adjustment process. The reduction of the coefficient to 0,045868 in 2024 suggests a weakening of the previous production

linkage between these sectors. The a41 coefficient also increased until 2022 and then declined significantly. This reflects a reduced share of sector 4 resources used in sector 1 production. The post–2023 decline may indicate a restructuring of intersectoral material flows. The coefficient rose from 0.02106 in 2022 to 0.12633 in 2023 and remained comparatively high at 0.10803 in 2024. This result indicates a substantial increase in the internal input intensity of the electricity sector.

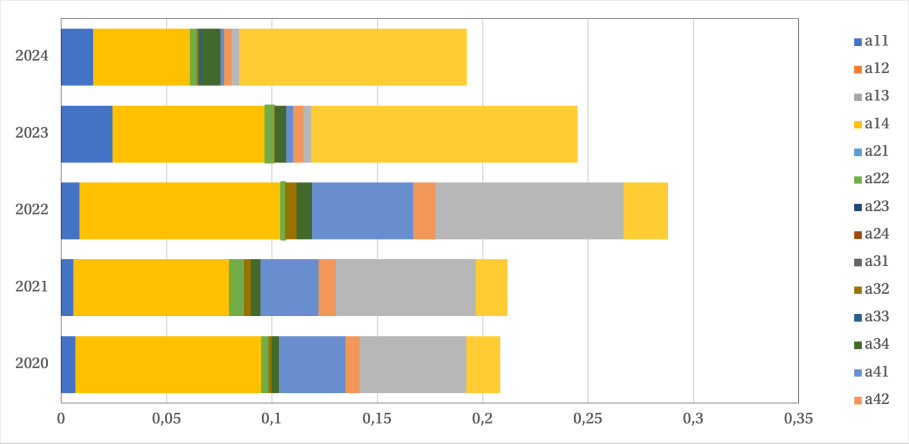


Figure 1. Technical coefficients of the energy subsystem for 2020–2024

Because these coefficients are calculated from monetary input–output tables, their changes may reflect shifts in input structure, relative prices, or statistical classification. Therefore, they should not be attributed exclusively to technological restructuring without additional decomposition analysis. Conversely, the coefficients a12, a13, a21, a23, a24, and a31 remained zero or close to zero throughout the study period. This indicates that the corresponding direct input requirements between these specific sector pairs were negligible within the four-sector energy subsystem. However, it does not imply that the overall intersectoral relationships of these sectors were weak.

Overall, the annual technical coefficient matrices reveal non-uniform changes in the structure of Kazakhstan's energy subsystem during 2020–2024. Although some intersectoral linkages weakened, dependence among the energy sectors increased in several areas, reflecting the redistribution of resource flows and changes in the production structure.

Based on the annual technical coefficient matrices, the corresponding Leontief inverse matrices were calculated as (I – At)-1 were obtained for 2020-2024. The resulting output multipliers are presented in Figure 2.

The results show that the electricity sector recorded the highest output multiplier throughout the study period. Its diagonal element was 1,019393 in 2020, increased to 1,027066 in 2022, and rose sharply to 1,144935 in 2023. Although it slightly declined to 1,121163 in 2024, it remained the highest among all sectors, indicating that the electricity sector functions as the core sector of Kazakhstan's energy system. This result suggests that the electricity sector (sector 4, i.e., element

4.4) is not only an energy producer but also a key sector that influences the production structures and intersectoral linkages of the other energy sectors (coal, oil, and gas). The sharp increase observed in 2023 indicates a strengthening of indirect production relationships and a higher degree of structural interdependence within the energy system. The multiplier coefficient of the coal industry (industry 1, that is, element 1.1) is relatively stable, between 1,009729 and 1,025217, indicating that its systemic impact is low but stable. This reflects coal's status as a key economic resource, although its structural impact remains weaker than in power generation.

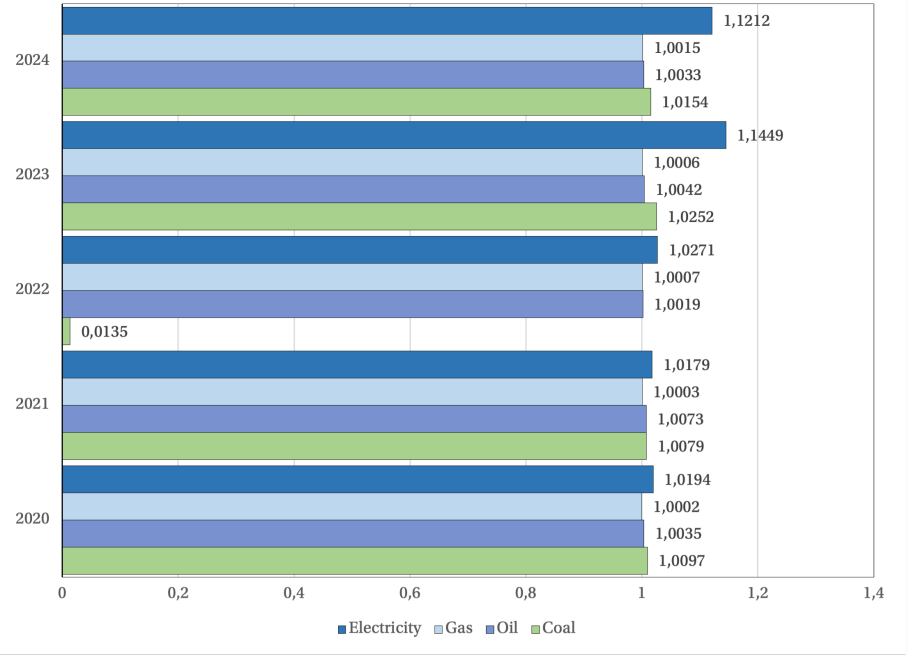


Figure 2. Diagonal elements of the Leontief inverse matrix for 2020–2024

The petroleum industry (industry 2, that is, element 2.2) has the lowest multiplier effect, always between 1,001863 and 1,007335. This indicates that its production links are weak, with relatively weak multiplier effects and limited indirect production linkages within the energy system. The multiplier effect of the natural gas sector (sector 3, that is, element 3.3) is also low (about 1,000179-1,001527), indicating that its role in the energy system is relatively small. However, it is expected to grow slightly by 2024. Overall, the results show a structural asymmetry in Kazakhstan's energy system: the electricity sector is the central node of the energy production network, coal remains a stable, basic resource, and the multiplier effect of oil and natural gas is relatively weak. Therefore, the Leontief input-output analysis demonstrates how the direct and indirect production linkages among the energy sectors changed during 2020-2024 and provides a quantitative assessment of the energy system's structural transformation.

Based on the Leontief inverse matrices, backward linkage (BL) and forward

linkage (FL) indicators were obtained for each sector and year. Figure 3 presents the BL indicators, while Figure 4 presents the corresponding FL indicators for 2020-2024.

Figures 3 and 4 present BL and FL indicators, respectively, for Kazakhstan's energy sectors during 2020-2024.

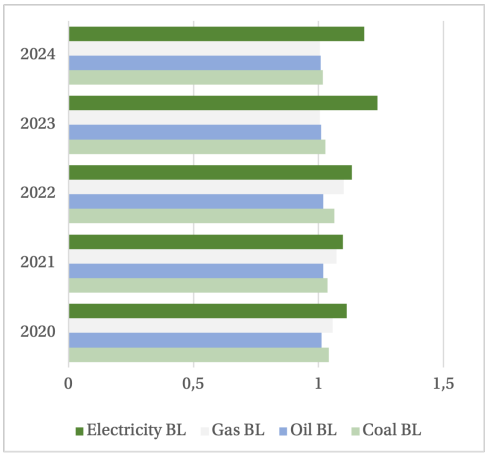


Figure 3. BL in the energy system for 2020-2024

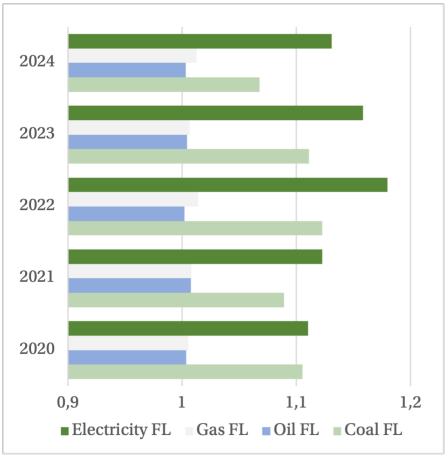


Figure 4. FL in the energy system for 2020-2024

BL and FL indicators from 2020 to 2024 reveal a gradual structural evolution in Kazakhstan's energy system. The BL indicator measures the degree of resource dependence in production sectors, highlighting how the system's cost structure evolves. In contrast, the FL indicator reflects a sector's capacity to distribute its products across the economic system, capturing their multiplier effects and overall influence. Examining these two indicators together provides a comprehensive understanding of the structural transformation of the energy sector, both in terms of production relationships and systemic interdependence.

The coal industry BL index showed only moderate fluctuations, peaking in 2022 and then gradually declining in 2024. The FL index also remained relatively stable, indicating that coal played a stable but not dominant role in providing energy to other energy sectors during the study period. The oil sector exhibits the most stable BL values, remaining virtually unchanged over time, suggesting a stable production structure and low resource dependence. In contrast, FL values were very high in 2020, indicating a relatively limited driving effect on the overall energy system, and they gradually declined in subsequent years, reaching their lowest point around 2023. This trend indicates a waning systemic influence of the oil sector and a broader diversification within the energy mix.

During the study period, the BL and FL values for the oil industry were the most stable. Both indicators were close to 1, indicating a relatively weak multiplier effect and limited changes in inter-industry production relations.

Compared with other industries, the BL value in the natural gas industry fluctu-

ated significantly, showing continuous growth until 2022, followed by a decline in 2023-2024. In contrast, the FL value remained relatively stable, indicating that its role as a supplier to the energy system has changed only marginally. Among all sectors, the energy sector consistently had the highest BL value, peaking significantly in 2023. Its FL value remained relatively high during the study period, confirming its central role in maintaining intersectoral production linkages in Kazakhstan's energy system.

Overall, the BL and FL indicators suggest that the intersectoral structure of Kazakhstan's energy system remained relatively stable during 2020-2024, although moderate changes in sectoral linkages were observed. The electricity sector consistently exhibited the strongest intersectoral influence, while the oil sector remained the most stable. Coal and natural gas experienced moderate variations, reflecting gradual adjustments in production relationships rather than fundamental structural transformation.

5 | CONCLUSION

This study examined how different parts of Kazakhstan's energy sector interacted from 2020 to 2024. This study used comparative input-output analysis based on annual Leontief input-output tables to examine the evolution of inter-industry production linkages in Kazakhstan's energy sector from 2020 to 2024. The analysis focuses on coal, oil, natural gas, and electricity production to assess changes in technological coefficients, inter-industry linkages, and production structure over time.

We found that the energy system slowly changed its structure over these years. How technology was used showed that some parts of the energy sector became less dependent on one another, while others became more internally connected. For example, the electricity sector relied more on its own production, meaning it used more resources from within the energy system and became more important overall. Coal and natural gas exhibited changes in their intersectoral production linkages, with several technical coefficients increasing through 2022 and then declining.

By looking at the connections between energy sectors, we could see the ripple effects. The electricity sector had the biggest impact on the whole system. Leontief's inverse analysis showed that the electricity sector consistently has the highest multiplier effect among the industries analyzed. Its multiplier effect increased significantly in 2023 and remained relatively high in 2024, confirming the central role of electricity generation in the energy system. The electricity sector functions as the central production node within Kazakhstan's energy system, generating the strongest direct and indirect intersectoral effects.

The coal industry multiplier remained relatively stable during the study period, indicating that it continues to play a supporting role in the production system. The oil industry showed the most stable technical and multiplier characteristics, with its BL and FL values approaching 1, indicating relatively weak indirect production linkages. The natural gas industry showed moderate fluctuations, especially in its BL value, indicating a gradual change in its production relations with other energy

sectors.

We also looked at how much each sector relied on others (Backward linkage) and how much it influenced others (Forward linkage). These helped us better understand their roles. The Backward linkage results indicate moderate differences in sectoral dependence on intersectoral inputs. The Forward linkage results confirmed that the electricity sector became the primary driver of the entire system. The BL and FL indicators further confirm the role of each sector in the production system. Among the energy sectors analyzed, electricity consistently exhibited the highest BL value, reflecting its high dependence on intersectoral resources and its central position in the production network. The relatively stable FL values for each sector indicate that the overall structure of intersectoral supply relations has undergone only gradual changes during the study period. In conclusion, these indicators suggest that Kazakhstan's energy system has undergone moderate structural changes rather than a radical transformation.

Thus, the comparative input-output analysis proved an effective approach for assessing changes in intersectoral linkages, the structural transformation of the production system, and the evolving interdependence among Kazakhstan's energy sectors. These findings are important for creating energy policies, improving how production is organized, and making smart choices to keep the energy system strong for the long run.

From a social perspective, the impact of structural changes in Kazakhstan's energy sector extends far beyond industrial production. Strengthening intersectoral linkages may contribute to employment stability, energy supply security, and regional economic development by improving the efficiency of energy production and resource allocation. A more balanced energy mix can also help lay a strong foundation for implementing long-term public policies to enhance national energy security and achieve sustainable economic growth and social well-being. The results of this study can help policymakers develop evidence-based energy strategies that combine economic efficiency with broader social development goals.

What we found also shows that the energy sector needs modern technology, more efficient resource use, and stronger links among its different parts. To make the system more stable in the future, it will be key to strengthen electricity's role as basic infrastructure, use more domestic resources, and improve how different sectors work together with technology.

However, our study had some limits. The analysis was based on a reduced four-sector input-output framework representing Kazakhstan's main energy industries, rather than the complete national input-output table. Therefore, the estimated multipliers characterize structural relationships within the energy subsystem rather than the entire national economy. Also, we mainly focused on economic connections and did not really consider environmental pollution or carbon emissions. So, future research could build on this by including environmental factors, such as carbon emissions and waste, and by adding the renewable energy sector. Furthermore, this analysis was conducted annually using comparative input-output tables and therefore does not account for capital accumulation,

investment dynamics, or time lags inherent in dynamic input-output models.

AUTHOR CONTRIBUTIONS

Writing – Original Draft: Baglan Tleulina, Aslan Tasmaganbetov, Aigul Kurmanalina.
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Development of Research Methodology: Baglan Tleulina, Aslan Tasmaganbetov.
Software and Supervisions: Baglan Tleulina.
Data Collection, Analysis, and Interpretation: Baglan Tleulina, Aslan Tasmaganbetov.
Visualization: Baglan Tleulina, Aigul Kurmanalina.
Writing Review and Editing Research: Baglan Tleulina, Aslan Tasmaganbetov, Aigul Kurmanalina.

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Executive Branch Turnover and Non-Resource Economic Growth in Kazakhstan: An Event-Study Analysis

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Abstract
The development of the non-resource sector largely depends not only on the foreign economic environment but also on the stability of public administration institutions and the continuity of economic policy. This study examines the dynamics of non-resource economic performance around major changes in government leadership in Kazakhstan using an event-study framework. The empirical base covers 1995-2019 and includes annual data from the Bureau of National Statistics of the Republic of Kazakhstan, the International Monetary Fund, information on prime minister and minister appointments, and oil price indicators. The study uses descriptive analysis, basic OLS regression, an event-study specification, and robustness checks; standard errors are calculated using the Newey–West HAC method. In the baseline model, the MajorResh coefficient was negative but statistically insignificant for both non-resource GDP ($\beta = -2.95$; p = 0.192) and the manufacturing industry ($\beta = -1.37$; p = 0.265). At the same time, the event-study analysis revealed a statistically significant decline in the nominal growth of non-resource GDP in the year of the prime minister's change ($\beta = -4.94$; p = 0.016) and a negative relationship in the following year ($\beta = -4.65$; p = 0.074). Additional analysis showed a statistically significant negative relationship between changes in the minister of industry and manufacturing output ($\beta = -4.40$; p = 0.008), while changes in the minister of finance showed no statistically significant results. The results indicate that the rotation of executive power is primarily associated with a short-term deterioration in the performance of the non-resource economy.

KEYWORDS
Economic Growth, Non Resource Economy, Economic Policy, Institutional Stability, Public Administration, Industry, Industrial Policy

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1 | INTRODUCTION

The impact of political instability on macroeconomic dynamics remains an important area of research in political economy and institutional macroeconomics. Existing theoretical approaches generally emphasize the relationship between the stability of executive institutions, economic policy uncertainty, economic agents' planning horizons, and the state's ability to maintain institutional continuity and policy consistency.

The relevance of the present study stems from the fact that the existing literature has focused predominantly on complete government changes in parliamentary democracies, electoral cycles, and changes in national political leadership. Much less attention has been devoted to systematic intra-term rotation of prime ministers and ministers within highly centralized presidential systems, a governance model characteristic of many post-Soviet and developing economies, including Kazakhstan. In such institutional settings, political stability at the presidential level may coexist with relatively frequent changes in the executive branch, raising questions about the implications of administrative turnover for economic policy continuity and economic performance.

This study examines the relationship between frequent changes in prime ministers and government teams and macroeconomic stability and non-resource economic growth in Kazakhstan within a highly centralized presidential system. It pays particular attention to whether major government reshuffles are associated with changes in non-oil economic growth and manufacturing performance before, during, and after such events.

Within this study, the concept of the "On-Duty Doctor's Logbook" is proposed as an analytical framework for describing a governance model characterized by frequent changes in executive teams. The framework is based on the idea that high administrative turnover may encourage greater attention to short-term responses to immediate socio-economic challenges, while implementing long-term structural reforms requires greater institutional continuity and policy consistency. Like an on-duty doctor focused on stabilizing a patient's immediate condition during a limited period, frequently rotating government teams may be incentivized to prioritize quickly observable administrative outcomes. At the same time, addressing deeper structural constraints may require longer planning horizons, accumulated institutional expertise, and continuity in implementing public policy.

The present study therefore represents a first step toward developing an analytical framework for understanding the relationship between the frequency of executive turnover and the continuity of economic governance. Existing academic literature provides limited empirical evidence regarding the frequency of ministerial turnover that may be compatible with effective governance and sustained policy implementation. This gap limits the evidence base for assessing the potential economic consequences of frequent executive rotation, particularly in countries where the president retains substantial authority to appoint and dismiss the government and exercises considerable influence over the broader political system (Fish, 2006).

In this context, the frequency of changes in prime ministers and government teams can be regarded as an important indicator of administrative continuity within the public governance system. Frequent cabinet rotation may create additional uncertainty for businesses and investors through shifts in economic policy priorities, revisions to reform implementation mechanisms, and changes in managerial approaches. Such changes may also affect the continuity of state programs, industrial policy, infrastructure projects, and other long-term development initiatives that require coordinated implementation over extended periods.

This study examines the dynamics of non-resource economic performance around major changes in government leadership in Kazakhstan using an event-study framework. This study contributes to the literature in three respects. First, it examines intra-term executive turnover in a highly centralized presidential system, a setting that has received considerably less attention than government changes in parliamentary democracies. Second, it applies an event-study framework to examine the dynamics of non-resource economic indicators before, during, and after major government reshuffles. Third, it introduces the "On-Duty Doctor's Logbook" concept as an analytical framework for interpreting the potential trade-off between short-term administrative responsiveness and long-term institutional continuity.

2 | LITERATURE REVIEW

According to the literature, one key channel through which political instability affects macroeconomic dynamics is the shortening of planning horizons among public authorities and private-sector actors. In Alesina et al. (1996), political instability is viewed as a factor that intensifies economic policy uncertainty, under which political elites facing a high probability of resignation or government replacement become more inclined to implement short-term, rapidly observable measures rather than consistently pursuing structural reforms and long-term transformations.

The study also notes that frequent leadership and government team changes are accompanied by growing uncertainty about future tax, fiscal, and regulatory policy parameters. In the literature on economic policy uncertainty, this mechanism is considered a factor contributing to lower investment activity, slower job creation, and weaker economic growth dynamics due to deteriorating expectations among economic agents.

Dirks and Schmidt (2024) provide similar evidence, using data from 34 developed economies over 1996–2020 and a panel vector autoregression model with instrumental variables, and find that an increased probability of government change is associated with weaker economic growth. Gurgul and Lach (2013) reach similar conclusions, finding that indicators of political instability, including government turnover, are systematically associated with weaker economic growth performance, based on evidence from two decades of post-communist transition in Central and Eastern Europe.

In the context of developing and transition economies, the study by Aisen and

Veiga (2013) demonstrates that each additional cabinet change per year, defined as the appointment of a new prime minister and/or replacement of 50% of ministers, reduces annual GDP per capita growth by 2.39 percentage points. The main transmission channel is a decline in productivity growth, which accounts for more than half of the effect, and, to a lesser extent, the accumulation of physical and human capital.

Evidence from presidential systems further supports the relevance of cabinet stability for economic performance. Kim (2018), using time-series cross-sectional data for 111 presidential systems over 1990–2015, finds that frequent changes of cabinet ministers are systematically associated with lower economic growth, while less predictable cabinet changes are associated with greater economic volatility. Nevertheless, much of the earlier literature focuses on complete government changes, electoral cycles, or changes in national leadership rather than intra-term ministerial turnover within presidential systems.

According to the existing literature, ministerial turnover and cabinet reshuffles have received limited attention, with most studies focusing primarily on parliamentary democracies and the new democracies of Central and Eastern Europe. Huber and Martínez-Gallardo (2008), as well as subsequent studies by Indriðason and Kam (2008), show that individual ministerial stability is only weakly correlated with overall cabinet stability. It is determined primarily by problems of selecting competent personnel and controlling "ministerial drift" – deviations of ministers from the prime minister's policy line within the framework of the principal-agent problem. Cabinet reshuffles thus serve as instruments of discipline and minimization of control losses (Huber & Martínez-Gallardo, 2008; Indriðason & Kam, 2008).

Research on presidential systems also suggests that ministerial turnover may be a strategic response to changing political and policy circumstances rather than merely a source of instability. Martínez-Gallardo (2014), using an original dataset on individual cabinet changes in 12 Latin American presidential systems between 1982 and 2012, shows that presidents use ministerial replacements to respond to unexpected shocks and adjust the composition of government to changing political conditions. In the work of Grotz et al. (2024), based on 131 cabinets across 11 countries in the region during 1990–2018 and using linear regressions with country and decade fixed effects, frequent cabinet reshuffles are shown to significantly reduce the prime minister's ability to effectively perform core functions, including coordination of public policy, resolution of intra-cabinet conflicts, and control over the bureaucratic apparatus. The strongest negative effect is observed when ministers from coalition parties outside the prime minister's party are replaced. The authors attribute this effect primarily to the lower experience level of newly appointed ministers, increased internal contradictions within the cabinet, and more complicated mechanisms of control over the state apparatus. One key channel of negative impact identified by the study is the loss of accumulated expertise and the disruption of institutional continuity in public administration (Grotz et al., 2024). A complementary typology developed by Helms and Vercesi (2024) further

distinguishes reshuffles by mode and scope, offering a conceptual framework for situating the frequent intra-term reshuffles observed in Kazakhstan.

The consequences of ministerial instability may extend beyond cabinet organization to policy implementation. Belchior and Silveira (2023), using evidence on ministerial instability and government pledge fulfillment in Portugal over 1995–2019, find that greater portfolio instability is associated with lower levels of policy commitment fulfillment, particularly at the junior ministerial level and in politically salient ministries. Their findings support the argument that personnel continuity may matter for accumulated administrative expertise and consistent implementation of government programs.

Izu (2026) presents direct quantitative estimates of the macroeconomic consequences of frequent cabinet reshuffles. According to the econometric analysis, each additional cabinet reshuffle is associated with a reduction in annual GDP per capita growth rates by 1.7–2.9 percentage points depending on the model specification used. These estimates support the hypothesis that political instability may affect economic dynamics by increasing uncertainty and shortening planning horizons among economic agents (Izu, 2026; Bedasso, 2024).

Studies and analytical reports on the United Kingdom provide additional evidence of the institutional costs of high ministerial turnover, where cabinet reshuffles traditionally occur frequently. The parliamentary report of the House of Commons Political and Constitutional Reform Committee (2013–2014), as well as the report of the Institute for Government (2020), based on opinions of experts, former ministers, and civil servants, note that high personnel turnover creates incentives for short-term policymaking, complicates the advancement of long-term projects, and weakens the stability of ministerial teams. The authors emphasize that limited tenure in office reduces ministers' ability to master their portfolios and build stable relationships with the state apparatus, complicating consistent policy implementation and the transfer of institutional memory (Sasse et al., 2020).

At the same time, ministerial turnover should not be interpreted as uniformly detrimental. Dewan and Dowding (2005), using evidence from the United Kingdom, show that ministerial resignations may serve a corrective function by enabling governments to respond to perceived failures and regain political support. Evidence of similar costs of leadership turnover outside parliamentary and Western contexts is provided by studies of local officials in China, where frequent replacement of city-level leaders has been shown to reduce urban economic efficiency, in part through weaker credit allocation and less efficient use of land resources (Ji et al., 2022), suggesting that the economic costs of executive turnover are not confined to any single type of political system.

Recent evidence also highlights the potential endogeneity of ministerial turnover. Schmid and Nyrup (2026), using data on more than 2,800 finance ministers from 1966–2021, show that economic performance is related to the political survival of finance ministers, though the relationship varies substantially across regime types. In democracies, stronger economic growth is associated with a greater probability of retaining finance ministers, whereas this relationship is

considerably weaker in autocracies. These findings matter for studies of executive turnover because they suggest that economic performance may influence personnel decisions, complicating a purely causal interpretation of the relationship between ministerial changes and subsequent economic outcomes.

Methodological approaches to identifying the economic consequences of political leadership changes remain diverse. Some studies rely on plausibly exogenous leadership shocks, such as unexpected deaths of national leaders (Jones & Olken, 2005), while others examine political uncertainty through its effects on asset prices and risk premia (Pástor & Veronesi, 2013). However, quasi-experimental evidence specifically addressing intra-term cabinet reshuffles remains comparatively limited.

Studies on public administration and administrative reforms in post-Soviet states provide additional context for understanding how executive power functions in Kazakhstan. Knox (2008), examining the modernization of public administration in Kazakhstan, argues that reforms were implemented within a highly centralized presidential system in which the presidency played a decisive role in defining national development priorities. Building upon this perspective, Knox and Orazgaliyev (2025) analyze the evolution of public administration in Kazakhstan through the lens of post-Soviet institutional legacies and modernization processes. Their study shows that under a strong presidential system, administrative coordination, institutional stability, and public institutions' capacity to implement long-term strategic priorities become particularly important.

Despite the growing literature, several important research gaps remain. First, most existing studies focus on parliamentary democracies, electoral transitions, changes of national leaders, or complete cabinet changes, whereas systematic evidence on intra-term executive turnover in highly centralized presidential systems remains limited. Second, relatively few studies examine the macroeconomic consequences of government-team changes while distinguishing dynamics before, during, and after major reshuffles. Third, the potential endogeneity of executive turnover remains an important methodological issue, since deteriorating economic conditions may themselves contribute to decisions to replace ministers or government teams.

3 | METHODOLOGY

Kazakhstan's institutional configuration from 1995 to 2019 provides a relevant setting for examining the relationship between executive turnover and macroeconomic dynamics. For most of the period under consideration, the country was characterized by a highly centralized presidential system, while prime ministers and cabinet members changed relatively frequently. The average tenure of a prime minister was approximately 2–2.5 years. These relatively short tenures may have limited the time available to implement long-term structural transformations, particularly in infrastructure, industrial, and institutional policy, where multi-year managerial and institutional continuity is important. In addition, several periods saw substantial personnel changes within the economic bloc, sectoral ministries,

and development institutions.

This institutional configuration combined a relatively stable political framework with considerable variability in the executive branch's composition. A significant share of government initiatives, programs, and reforms was implemented amid regular renewal of management teams, shifts in socio-economic policy priorities, and changes in policy implementation mechanisms. This feature is particularly relevant for Kazakhstan as a resource-dependent economy, since sustainable development in non-resource sectors requires long-term planning, consistent industrial policy, and continuity in implementing infrastructure projects. Regional panel evidence for Kazakhstan also indicates that institutional quality represents an important channel through which resource concentration affects non-resource economic performance (Oskenbayev et al., 2013). Frequent changes in executive leadership may therefore alter the balance between short-term stabilization measures and longer-term structural transformation.

The study covers the period 1995–2019. The starting year reflects the adoption of the Constitution of the Republic of Kazakhstan in 1995, which established the institutional framework of the presidential system and shaped the subsequent organization of executive power. The period therefore provides a comparatively stable institutional setting for examining changes within the executive branch. However, the presidential transition in 2019 should be considered when interpreting the final year of the sample.

For the empirical analysis, an event-study framework is applied. Changes in the Prime Minister are treated as discrete political events around which the dynamics of macroeconomic indicators are examined. The empirical strategy does not assume that prime-ministerial turnover is fully exogenous. Rather, it evaluates whether systematic changes in economic performance can be observed before, during, and after changes in executive leadership. Accordingly, the estimated coefficients represent conditional associations rather than strictly causal effects.

The main advantage of the event-study framework is its ability to distinguish economic dynamics before the event, during the government reshuffle, and after the event. This makes it possible to assess whether changes in macroeconomic indicators are concentrated around periods of executive turnover and whether any observed association persists after the reshuffle.

To distinguish the pre-event, event-year, and post-event periods, the study estimates the following event-time specification (1):

$$\begin{aligned} Y_t = \alpha + \beta_{-1} D_{-1,t} + \beta_0 D_{0,t} + \beta_{+1} D_{+1,t} \\ + \gamma_1 \, Oil_Urals_t + \gamma_2 \, W_GDP_t + \gamma_3 \, USD_KZ_t + \varepsilon_t \end{aligned} \tag{1}$$

where:

Y_t – the dependent macroeconomic variable in year t;

$D_{-1,t}$ – the binary indicator equal to 1 in the year preceding a MajorResh event and 0 otherwise;

$D_{0,t}$ – the binary indicator equal to 1 in the year of a MajorResh event and 0 otherwise;

$D_{+1,t}$ – the binary indicator equal to 1 in the year following a MajorResh event and 0 otherwise.

The dependent variables are nominal non-oil GDP growth (percentage change from the previous year) and the index of physical volume of manufacturing output (IFOman, percentage relative to the previous year). These indicators were selected because they are less directly influenced by oil-sector fluctuations than aggregate GDP and may therefore provide a more informative measure of developments in the non-resource economy. Manufacturing output is also relevant for assessing changes in sectors that depend on industrial policy, institutional continuity, and the consistent implementation of government programs.

Data on non-oil GDP growth were obtained from the Bureau of National Statistics of the Republic of Kazakhstan and the International Monetary Fund. Data on the manufacturing output index were obtained from the Bureau of National Statistics (2025). Annual rather than quarterly data were used because of the limited availability and comparability of quarterly historical data for the early years of the study period and to ensure a consistent time series throughout the analysis.

The available non-oil GDP series is expressed in current prices and is therefore not adjusted for inflation. This feature partly explains the relatively high average annual growth rates observed during 1995–2019, a period characterized by substantial inflation and exchange-rate depreciation. Consequently, the variable should be interpreted as nominal non-oil GDP growth rather than real economic growth, and the magnitude of the estimated coefficients should be interpreted with appropriate caution. Future research should reconstruct a comparable real non-oil GDP series.

The key explanatory variable, MajorResh, is a binary indicator of prime-ministerial turnover. It equals 1 in years in which a new Prime Minister of the Republic of Kazakhstan took office and 0 otherwise. In the empirical analysis, prime-ministerial turnover is used as a proxy for a major change in executive leadership. The following years are classified as MajorResh events: 1997, 1999, 2002, 2003, 2007, 2012, 2014, 2016, and 2019, for a total of nine events. Additional indicators capture turnover of the Minister of Industry (TurnInd) and the Minister of Finance (TurnF). Information on prime-ministerial and ministerial appointments was collected from official presidential decrees published on the Akorda.kz website.

The dataset also identifies 1995 as a year of prime-ministerial appointment. However, this observation is excluded from the event-time estimation because the pre-event period cannot be constructed for the beginning of the sample. The empirical analysis therefore uses the nine MajorResh events occurring between 1997 and 2019. TurnInd and TurnF are constructed analogously as binary variables equal to 1 in years in which a new Minister of Industry or Minister of Finance, respectively, took office. Because the industry portfolio was repeatedly renamed and, during part of 1997–2001, combined with energy and trade functions, the TurnInd indicator is considered more reliable from 2002 onward.

Because prime-ministerial changes occurred in consecutive years in 2002 and

2003, some event windows overlap. The corresponding coefficients should therefore be interpreted as average event-time associations rather than as the effects of completely isolated political events. Table 1 presents descriptive statistics for the main variables used in the empirical analysis.

Table 1. Descriptive statistics for the main variables

Variable	N	Mean	SD	Min	Max
Nominal non-oil GDP growth, % y/y	24	20.15	9.19	6.00	43.89
Manufacturing output index (previous year = 100)	25	103.65	7.97	83.70	122.80
MajorResh (0/1)	25	0.40	0.50	0	1
Urals oil price, USD/bbl	20	62.64	29.36	23.10	110.40
World GDP growth, %	25	3.16	1.20	−1.34	4.53
KZT/USD exchange rate	25	166.81	88.53	60.95	382.75

Note: compiled by the authors

The model includes three control variables: the average annual price of Urals crude oil, the annual growth rate of world GDP, and the average annual nominal exchange rate of the Kazakhstani tenge against the US dollar. These variables are included to account for external economic conditions that may simultaneously affect Kazakhstan's non-resource economic performance and coincide with changes in executive leadership.

The baseline econometric specification takes the following form (2):

$$Y_t = \alpha + \beta\, MajorResh_t + \gamma_1\, Oil_Urals_t + \gamma_2\, W_GDP_t + \gamma_3\, USD_KZ_t + \varepsilon_t \quad (2)$$

where:

Y_t – the dependent variable in year t;
$MajorResh_t$ – the binary indicator of prime-ministerial turnover;
Oil_Urals_t – the average annual price of Urals crude oil;
W_GDP_t – the annual world GDP growth;
USD_KZ_t – the average annual nominal KZT/USD exchange rate.

Overall, the empirical strategy combines descriptive analysis, stationarity testing, a basic regression model, an event-study approach, and robust results tests. To account for possible heteroskedasticity and autocorrelation, Newey–West HAC standard errors are used. Given the small sample size, overlapping event windows, the presidential transition in 2019, and the nominal nature of the non-resource GDP series, the coefficients are interpreted with caution as conditional relationships rather than strictly causal effects. The following section presents results from the baseline model, event-study analysis, and robustness checks.

4 | RESULTS

The empirical analysis begins by comparing macroeconomic indicators between years with and without prime-ministerial turnover. The quasi-experimental anal-

ysis using the Event-Study method indicates a relationship between major government reshuffles and the dynamics of non-resource economic growth and the manufacturing industry. In years with major cabinet reshuffles (MajorResh = 1), the average growth rate of non-oil GDP was 16.07%, whereas in years without major reshuffles it was 22.60%. Thus, after controlling for external economic conditions, the negative differences observed in the descriptive comparison remain directionally consistent but are not statistically significant in the baseline specification. Table 3 presents the full regression results, including the coefficients of the control variables.

Table 2. Comparison of average macroeconomic indicators by prime-ministerial turnover status

Indicator	MajorResh = 0	MajorResh = 1	Difference (p.p.)
Non-oil GDP growth rate, %	22.60	16.07	-6.53
Manufacturing output index (previous year = 100)	104.53	102.33	-2.20

Note: compiled by the authors

The baseline OLS regression results, controlling for the average annual price of Urals crude oil, world GDP growth, and the KZT/USD exchange rate, indicate a negative but statistically insignificant association between prime-ministerial turnover and both dependent variables at conventional significance levels. For nominal non-oil GDP growth, the estimated coefficient on MajorResh is -2.95 (HAC-robust SE = 2.26; p = 0.192). For the manufacturing output index, the corresponding coefficient is -1.37 (HAC-robust SE = 1.23; p = 0.265). Thus, after controlling for external macroeconomic conditions, the negative differences observed in the descriptive comparison remain directionally consistent but are not statistically significant in the baseline specification. Table 3 presents the full regression results, including the coefficients of the control variables.

Table 3. Baseline OLS regression results for nominal non-oil GDP growth and manufacturing output

Variable	Non-oil GDP growth	Manufacturing IFO
MajorResh	-2.95 (2.26) [0.192]	-1.37 (1.23) [0.265]
Oil_Urals	-0.03 (0.03) [0.320]	-0.08 (0.03) [0.013]
W_GDP	3.27 (0.50) [0.000]	2.58 (0.46) [0.000]
USD_KZ	-0.04 (0.01) [0.000]	-0.01 (0.01) [0.179]
Constant	20.48 (3.12) [0.000]	105.84 (2.98) [0.000]
N	20	20
R^2	0.575	0.581

Coefficients are reported with Newey–West HAC-robust standard errors (one lag) in parentheses and p-values in square brackets. MajorResh is a binary indicator of prime-ministerial turnover.

Note: compiled by the authors

The baseline regression results indicate a negative relationship between prime-ministerial turnover and both nominal non-oil GDP growth and manufacturing output. However, the estimated coefficients for MajorResh are not statistically significant at conventional levels. For nominal non-oil GDP growth, the coefficient is -2.95 ($p = 0.192$), while for the manufacturing output index it is -1.37 ($p = 0.265$).

Among the control variables, world GDP growth is positively associated with both dependent variables and is statistically significant in both models. The Urals oil price shows a statistically significant negative association with manufacturing output ($\beta = -0.08$; $p = 0.013$), but not with nominal non-oil GDP growth. The KZT/USD exchange rate is negatively associated with nominal non-oil GDP growth ($\beta = -0.04$; $p < 0.001$), whereas its coefficient for manufacturing output is not statistically significant.

Taken together, the descriptive comparison in Table 2, the baseline regression results in Table 3, and the event-study estimates in Table 4 show a broadly consistent pattern.

Table 4. Event-study specification: dynamics of macroeconomic indicators around major government reshuffles

Variable	Non-oil GDP growth	Manufacturing IFO
D_{-1} (year before reshuffle)	0.73 (2.77) [0.792]	-0.83 (1.51) [0.583]
D_0 (reshuffle year)	-4.94 (2.06) [0.016]	-2.91 (1.76) [0.098]
D_{+1} (year after reshuffle)	-4.65 (2.60) [0.074]	-2.00 (1.85) [0.282]
Oil_Urals	-0.05 (0.02) [0.035]	-0.09 (0.03) [0.003]
W_GDP	3.54 (0.29) [0.000]	2.70 (0.52) [0.000]
USD_KZ	-0.05 (0.01) [0.000]	-0.02 (0.01) [0.013]
Constant	24.52 (2.80) [0.000]	108.85 (3.31) [0.000]
N	19	19
R^2	0.670	0.652

Cell entries: coefficient (Newey-West HAC-robust standard error, 1 lag) [p-value]. D_{-1}, D_0 and D_{+1} are indicator variables equal to 1 in the year preceding, the year of, and the year following a MajorResh event, respectively.

Note: compiled by the authors

Prime-ministerial turnover is associated with lower nominal non-oil GDP growth, with the largest and statistically significant deviation observed in the turnover year. For manufacturing output, the coefficients are also negative, although they do not reach conventional levels of statistical significance after controlling for external macroeconomic conditions. Overall, the event-study results suggest that the relationship between prime-ministerial turnover and economic performance is most pronounced in the turnover year. Nominal non-oil GDP growth declines significantly in that year and remains negative the following year, though with weaker significance. No comparable pre-event decline is observed. For manufacturing output, the estimated coefficients follow the same negative pattern, but the evidence is weaker and does not reach the 5% significance level.

These results indicate that the association between executive turnover and economic performance is concentrated mainly around the timing of the turnover itself rather than in the period preceding it.

Figure 1 illustrates the dynamics of nominal non-oil GDP growth around the identified turnover years.

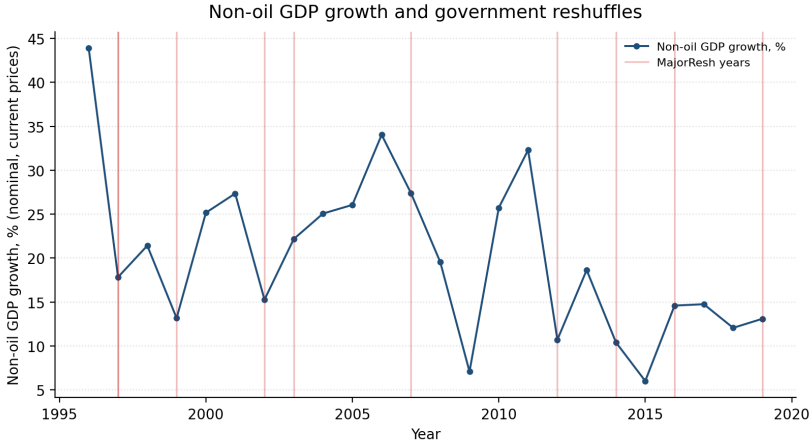


Figure 1. Nominal non-oil GDP growth and prime-ministerial turnover for 1995–2019

Figure 1 shows that nominal growth in non-resource GDP during the period under consideration was quite uneven. In several years coinciding with a change of prime minister, growth rates declined relative to previous periods, but this reaction was not uniform in all cases. The most noticeable deviations occur in individual years when the government changes, which generally aligns with the event-study results. Minister turnover, dated from actual presidential appointments rather than the raw cumulative indicators in the dataset, shows a pattern distinct from MajorResh. As Table 6 shows, replacing the Minister of Industry (TurnInd) is associated with a negative, significant coefficient for manufacturing output (-4.40; SE = 1.67; p = 0.008), while the non-oil GDP coefficient is small and insignificant (1.61; p = 0.598).

The results show differences in the nature of the relationship between personnel changes in individual ministries and economic indicators. The change of the Minister of Industry is associated with a decline in the index of the physical volume of the manufacturing industry: the coefficient is -4.40 and is statistically significant (p = 0.008). At the same time, the relationship with the nominal growth of non-resource GDP is statistically insignificant (β = 1.61; p = 0.598). No statistically significant relationships were identified for the change of the Minister of Finance. The results obtained suggest that personnel changes in the industrial sector are largely linked to sectoral dynamics rather than to the overall indicators of the non-resource economy.

These results warrant caution for two reasons. First, the exact within-year

timing of a ministerial appointment cannot be fully verified from annual data, so coefficients capture an association with the appointment year rather than a

Table 6. Ministerial turnover and economic performance

Variable	Nominal non-oil GDP growth	Manufacturing output index
Panel A. Minister of Industry turnover (TurnInd)	-	-
TurnInd	1.61 (3.04) [0.598]	-4.40 (1.67) [0.008]
N	20	20
R^2	0.553	0.674
Panel B: Minister of Finance turnover (TurnF)		
TurnF	0.19 (2.19) [0.929]	-2.25 (2.01) [0.262]
N	20	20
R^2	0.546	0.599

Cell entries: coefficients are reported with Newey–West HAC-robust standard errors (one lag) in parentheses and p-values in square brackets. All specifications include the same control variables as in Table 3. TurnInd and TurnF are binary indicators equal to 1 in years in which a new Minister of Industry or Minister of Finance, respectively, took office.

Note: compiled by the authors

precisely dated causal effect. Second, the mechanism is not directly tested: a plausible interpretation, consistent with the study's general hypothesis, is that a change in industry-sector leadership disrupts policy continuity and accumulated expertise, but reverse causality - weak performance prompting the minister's replacement - cannot be ruled out. The Minister of Finance result is directionally consistent with the same hypothesis but not statistically significant and should be read as a possible association rather than an established effect. The dynamics of the physical volume index of the manufacturing industry during the years of the prime minister's change are presented in Figure 2.

Figure 2 shows that the dynamics of the manufacturing industry in 1995–2019 were accompanied by noticeable fluctuations in the physical volume index. In some years, a change in the prime minister was accompanied by a decline in the indicator or a slowdown in its growth, but this reaction was not uniform in all cases. Visually, this corresponds to the overall negative direction of the coefficients obtained in the regression analysis, but this does not allow us to conclude that personnel changes had a causal impact on industrial dynamics. Overall, the figure confirms the presence of a temporal coincidence between certain episodes of executive rotation and the deterioration of sectoral indicators.

A model using a lagged MajorResh variable was also tested. The coefficient for the MajorResh_lag1 variable amounted to -3.58 (HAC-robust SE = 2.11; p = 0.090), retaining the same sign as the contemporaneous specification (see Table 5).

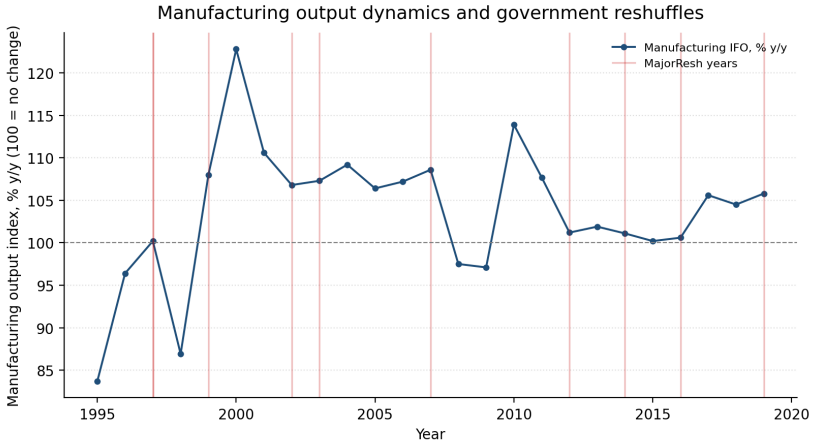


Figure 2. Manufacturing output dynamics and major government reshuffles for 1995-2019

Robustness checks included a linear time trend, a log-transformed dependent variable, an annual-growth-rate exchange-rate specification, and the lagged MajorResh variable above; results are in Table 5. A genuine year-fixed-effects specification is not identifiable here, since the dataset has only one observation per year and MajorResh would be perfectly collinear with year dummies; the linear time trend substitutes for this and captures any secular decline in growth. Across specifications, the MajorResh (or event-time) coefficient retained a negative sign, reaching significance in the time-trend ($p = 0.095$) and event-study reshuffle-year ($p = 0.016$) specifications, but not in the baseline or lagged ones. Thus, the results suggest a relationship between the frequency of government team changes and the dynamics of non-resource economic growth and manufacturing industry performance.

Table 5. Robustness of the prime-ministerial turnover coefficient across alternative specifications

Specification	Coefficient (HAC SE)	p-value	N
Baseline (Oil, W_GDP, USD level)	-2.95 (2.26)	0.192	20
With linear time trend	-3.76 (2.25)	0.095	20
Lagged MajorResh (t-1)	-3.58 (2.11)	0.090	20
USD_KZ as annual growth rate	-3.01 (3.28)	0.240	20
Event-study, reshuffle year (D_0)	-4.94 (2.06)	0.016	19
Event-study, year after (D_{+1})	-4.65 (2.60)	0.074	19

The coefficient column reports the estimated coefficient for MajorResh or the corresponding event-time indicator. Newey–West HAC-robust standard errors with one lag are reported in parentheses. MajorResh is a binary indicator of prime-ministerial turnover.

Note: compiled by the authors

5 | DISCUSSION

The results suggest that the impact of political instability on macroeconomic dynamics in Kazakhstan cannot be reduced solely to electoral cycles or changes at the head-of-state level. Under a stable presidential vertical, frequent intra-term rotation of prime ministers and government teams may also matter for understanding economic dynamics through institutional and administrative channels.

One key mechanism identified in the study's framework is the shortening of the effective planning horizon in public administration. Frequent replacement of government teams limits the time available to master sectoral specifics, build stable interaction with the bureaucratic apparatus, and ensure continuity in implementing state programs. Under such conditions, attention may shift toward short-term administrative measures, while implementing long-term reforms may require stronger institutional continuity.

The obtained results are generally consistent with the conclusions of Alesina et al. (1996), Aisen and Veiga (2013), Dirks and Schmidt (2024), and Grotz et al. (2024), who associate political instability and frequent cabinet reshuffles with rising uncertainty, weakening institutional continuity, and deterioration in economic dynamics. At the same time, the Kazakhstan case shows a specific institutional configuration in which the effects associated with administrative turnover emerge even without changes at the highest level of political authority. This result may indicate that institutional continuity within the executive branch itself is an independent factor in economic stability, particularly for economies characterized by a strong state role in investment allocation, industrial policy, and infrastructure development.

Particular attention should be devoted to the heterogeneous effects reported in Table 6. The negative, significant coefficient for the Minister of Industry on manufacturing output is broadly consistent with the study's general hypothesis: a change in industry-sector leadership may disrupt sector-specific policy continuity and accumulated expertise, analogous to the mechanism proposed for reshuffles. This also shows why turnover effects should not be read off a single long tenure: one official held the industry portfolio from 2009 to 2014, yet the coefficient across the full 1997-2019 sequence of appointments points the opposite way. Because the exact channel is not directly tested, read the result as an association consistent with the institutional-continuity hypothesis rather than a demonstrated causal mechanism; reverse causality cannot be excluded. In contrast, the Minister of Finance coefficient, while negative for manufacturing output, is not significant once turnover dates and HAC-robust errors are used, suggesting fiscal-leadership turnover may matter less than industry-portfolio turnover, though a modest negative association cannot be ruled out given the limited power of 20 annual observations.

The persistence of the negative coefficient in the lagged model additionally indicates that the consequences of major government reshuffles are not limited to short-term political effects. Part of the impact appears with a delay through channels associated with interruptions in implementation procedures, restructuring of management teams, revised priorities, and slower coordination between

state institutions. This result may point to the role of institutional memory and administrative continuity in sustaining medium-term economic growth.

Within this context, the concept of the "On-Duty Doctor's Logbook" proposed in the study may be interpreted as a model of public administration characterized by a predominantly reactive approach to economic governance. Frequent replacement of government teams may reduce the time available to accumulate sector-specific experience and ensure continuity in implementing state programs. Under such conditions, implementing long-term development initiatives may depend more on institutional continuity and policy consistency.

At the same time, the results obtained should not be interpreted as evidence that any personnel rotation necessarily produces negative economic consequences. A certain level of renewal within the executive branch remains necessary for adapting state policy to changing economic conditions, correcting ineffective decisions, and introducing new managerial approaches; indeed, cross-country evidence suggests that excessively long tenure in executive office can itself be associated with slower growth, higher inflation and declining institutional quality (Papaioannou & Van Zanden, 2015). However, the event-study pattern - a significant negative deviation in the reshuffle year and the year after, but not before - is consistent with the idea that a point may exist beyond which excessive turnover weakens institutional continuity. This study does not estimate a threshold or non-linear specification directly given the limited observations, so treat this as a hypothesis motivated by the event-study pattern rather than an established finding; testing it would require a larger or higher-frequency dataset.

The Kazakhstan case therefore shows that the effectiveness of public administration depends not only on the stability of supreme political leadership, but also on the executive branch's ability to preserve institutional continuity, accumulated expertise, and consistent implementation of strategic priorities over extended periods.

6 | CONCLUSION

The obtained results are consistent with the interpretation that frequent changes of prime ministers and members of the Government may be associated with short-term stabilization in certain sectors of the economy; whether this reflects genuinely faster crisis response is a plausible interpretation of the "On-Duty Doctor's Logbook" framework rather than a mechanism measured directly in this study, since the speed of government response to shocks and the effectiveness of specific anti-crisis measures are not observed in the data used here. However, the findings also suggest opportunities for deeper structural transformation and longer-term development initiatives.

The findings suggest that alongside short-term stabilization outcomes, the pace of infrastructure modernization, economic diversification, and long-term development initiatives may also depend on the degree of institutional continuity. Frequent rotation of management teams may influence the balance between short-term policy objectives and longer-term strategic priorities.

The study's scientific contribution lies in extending the literature on political instability and economic development by analyzing intra-term government turnover under conditions of a stable presidential vertical. In addition, the study introduces the concept of the "On-Duty Doctor's Logbook" as an analytical framework for explaining how frequent changes of government teams may affect institutional continuity and long-term economic policy implementation. From a practical perspective, the findings highlight the importance of administrative continuity and strategic consistency for successfully implementing structural reforms and industrial policy.

Despite these results, the study has several limitations typical of analyzing political-economic processes in countries with limited time-series observations. First, the relatively small sample size and the high concentration of political events during certain periods limit the statistical power of the estimates and the significance of individual coefficients.

Another limitation is potential endogeneity. In particular, the deterioration of the macroeconomic situation itself could have provoked more frequent changes in prime ministers and members of the Government. Despite the use of control variables and the quasi-experimental event-study design, it is not possible to fully rule out reverse causality.

Furthermore, the model does not fully allow a quantitative assessment of the influence of informal institutions, the quality of the state apparatus, differences in managerial competence among individual cabinets, and foreign policy factors that can affect economic dynamics.

Three further data-related limitations warrant note. First, the non-oil GDP series is nominal rather than inflation-adjusted, affecting the magnitude (though not necessarily the sign) of estimated coefficients; a real-terms reconstruction is left for future work. Second, the manufacturing-output regression shows residual autocorrelation (Durbin-Watson = 0.76), addressed here with HAC-robust errors but still pointing to unmodelled dynamics a longer series could capture. Third, TurnInd and TurnF were reconstructed from dated presidential appointments; because the industry portfolio was repeatedly renamed and merged with energy and trade for parts of 1995-2001, TurnInd is more reliable from 2002 onward, and Table 6's minister-level results should be read with this caveat.

The next stage of the research is expected to include decomposition of the existing dataset into quarterly observations, expansion of the cross-country sample through the inclusion of additional post-Soviet and developing economies, as well as the development of an analytical framework for estimating the optimal duration of ministerial tenure for effective sectoral governance and implementation of long-term structural reforms.

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Managerial Responses to Workforce Shortages in Hotel Operations: A Department-Level Analysis

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Abstract
Hospitality organizations continue to experience workforce shortages that affect operational performance, service quality, and employee well-being. These pressures may vary substantially across hotel departments, yet limited empirical attention has been given to how managers respond to department-specific staffing constraints. This study examines workforce shortages and managerial response strategies in hotel operations from a department-level perspective and investigates how specific workforce pressures relate to managerial responses. A mixed-method research design was employed, combining survey data from 70 hotel managers in Kazakhstan with qualitative evidence from seven semi-structured interviews. Descriptive statistics, the Friedman test, and Spearman's rank correlations were used to examine departmental differences and associations between workforce pressures and managerial responses. The highest level of shortage was observed in housekeeping ($M = 3.73$, $SD = 1.01$), followed by food and beverage ($M = 3.30$, $SD = 1.22$), kitchen ($M = 3.26$, $SD = 1.21$), and front office ($M = 3.07$, $SD = 1.36$); the lowest value was recorded in Engineering ($M = 2.37$, $SD = 1.05$). The correlation analysis revealed a positive relationship between burnout and salary increases ($\rho = .422$, $p < .001$), a shortage of skilled workers and automation ($\rho = .337$, $p = .004$), as well as seasonality and a reduction in the volume of services ($\rho = .417$, $p < .001$). The results show that management measures in the hospitality industry should consider the nature of the personnel problem and the department's specific characteristics, combining compensation, technological, and organizational tools.

KEYWORDS
Business, Hotel Business, Hospitality Industry, Workforce, Labour Market, Hotel Management, Managerial Response

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1 | INTRODUCTION

Hospitality organizations continue to face persistent workforce shortages that challenge service continuity, operational performance, and workforce stability. The problem is particularly acute in a labor-intensive industry marked by high employee turnover, demanding working conditions, irregular schedules, and reliance on direct service interaction (Baum, 2015; Baum et al., 2020). Post-pandemic changes in employee expectations, career preferences, and labour-market conditions have further intensified recruitment and retention difficulties (Popa et al., 2023; Magnini et al., 2024). Recent evidence also identifies persistent skill shortages, difficult working conditions, and limited career progression as important barriers to sustainable hospitality workforce development (Giousmpasoglou et al., 2025).

Workforce pressure, however, is not distributed uniformly across hotel operations. Departments differ in workload intensity, skill requirements, working schedules, customer contact, and opportunities for technological substitution. Labour-intensive units such as Housekeeping, Kitchen, and Food and Beverage may therefore experience different staffing constraints from front office or engineering. Yet much of the hospitality workforce literature has examined turnover, recruitment, and retention at the organizational or industry level rather than differences within hotel operations.

Previous research identifies multiple sources of hospitality workforce instability, including workload and burnout, skill shortages, compensation, career perceptions, and labour mobility (Baum et al., 2020; Popa et al., 2023; Magnini et al., 2024; Giousmpasoglou et al., 2025). However, understanding the sources of workforce instability does not fully explain how managers respond when these pressures affect daily operations. Managerial responses may include compensation adjustments, alternative recruitment strategies, service adjustments, and greater use of digital technologies and automation. Recent hospitality research indicates that automation and digital workers are increasingly considered in the context of labour scarcity, staff shortages, upskilling, and operational efficiency (Aluri et al., 2025). At the same time, technological change may generate employee uncertainty and job-related concerns (Chen & Cai, 2025).

Despite growing attention to hospitality workforce challenges, empirical evidence on managerial responses at the department level remains limited. In particular, it remains unclear whether managers rely on similar response strategies across hotel departments and how specific workforce pressures are related to the strategies adopted. Quantitative evidence is also rarely integrated with managers' explanations of how they implement workforce responses in operational settings.

Accordingly, this study examines workforce shortages and managerial response strategies in hotel operations from a department-level perspective and investigates how specific workforce pressures relate to managerial responses. The study addresses the following research questions:

RQ1. How does the perceived severity of workforce shortages vary across core hotel departments?

RQ2. Which workforce pressures and managerial response strategies are most prominent in hotel operations?

RQ3. How are workforce pressures related to managerial response strategies, and how do managerial interview insights help explain these relationships?

By shifting attention from workforce shortages as an industry-wide phenomenon to managerial responses within hotel operations, this study provides department-level evidence on staffing pressures and integrates quantitative survey findings with qualitative managerial insights. The findings also offer practical guidance for developing workforce responses that better reflect department-specific operational conditions.

2 | LITERATURE REVIEW

Workforce shortages in hospitality represent a persistent structural challenge affecting service quality, operational efficiency, and employee well-being (Baum, 2015; Baum et al., 2020). Due to the labour-intensive nature of hotel operations, workforce stability is critical for service continuity, particularly in frontline departments. Recent research indicates that staffing difficulties continue to reflect problems related to compensation, working conditions, career preferences, and changing workforce expectations (Popa et al., 2023; Magnini et al., 2024). Recent career research further emphasizes the combined role of individual, organizational, and socio-cultural factors in hospitality employee retention and career sustainability (Akosa et al., 2025).

The present study focuses on five recurring workforce pressures—wage competitiveness, migration, seasonality, burnout, and skill shortages—which capture both organizational demands and external labour-market constraints. Wage competitiveness affects the ability of hotels to attract and retain employees, while skill shortages constrain the availability of qualified workers (Baum, 2015; Magnini et al., 2024). Migration influences labour supply in a sector traditionally dependent on mobile workers, while seasonality creates fluctuations in staffing requirements. Recent tourism research also demonstrates the growing role of foreign workers in addressing labour shortages, while highlighting integration, language, and institutional challenges associated with reliance on migrant labour (Nnubia et al., 2025). Burnout reflects the consequences of sustained workload and demanding working conditions.

The Job Demands–Resources (JD-R) model provides a theoretical basis for understanding these pressures (Bakker & Demerouti, 2007). Sustained job demands can contribute to exhaustion and negative employee outcomes when adequate resources are unavailable. This is particularly relevant to hospitality, where irregular schedules, emotional labour, and intensive service interaction place considerable demands on employees. Hospitality research has linked such conditions to burnout, reduced engagement, and turnover-related outcomes (Karatepe, 2013; Karatepe et al., 2021). Workforce shortages may therefore become self-reinforcing as staffing deficits increase demands on remaining employees and further undermine workforce stability.

Skill availability represents a related challenge because hotel operations depend on occupational and service-specific competencies that cannot always be replaced rapidly. Recent research identifies skill shortages, difficult working conditions, and limited career progression as barriers to sustainable hospitality workforce development (Giousmpasoglou et al., 2025). Recent evidence from Kazakhstan similarly identifies skill deficiencies and seasonality-related turnover as persistent barriers to tourism workforce development, reinforcing the relevance of these pressures in the present study context (Özoğul Balyali et al., 2026). Research on the future of tourism work also emphasizes the interaction between labour shortages, skills constraints, migrant workers, and technological change (Yeoman & McMahon-Beattie, 2024).

Less attention, however, has been given to managerial responses when workforce shortages become an operational constraint. Managers may use wage adjustments, recruitment, migrant labour, process adaptation, and digital technologies or automation (Acemoglu & Restrepo, 2020; Davenport & Ronanki, 2018; Benbya et al., 2020). These responses may provide only partial solutions. Compensation does not necessarily address workload, burnout, or skill availability (Magnini et al., 2024), while technology can support efficiency without eliminating the need for skilled human labour and may create concerns related to job insecurity (Vrontis et al., 2022; Chen & Cai, 2025). Technology may therefore complement constrained labour supply rather than universally substitute for hospitality employees (Yeoman & McMahon-Beattie, 2026).

Another limitation is the tendency to examine workforce issues at the organizational or industry level rather than across individual hotel departments. Departments differ in workload intensity, skill requirements, customer interaction, and opportunities for technological support. From a JD-R perspective, these differences imply variation in job demands and available resources, making department-level analysis relevant to managerial decision-making. Moreover, the structural nature of hospitality workforce instability suggests that isolated interventions may be insufficient and that more coordinated responses are required (Iverson & Deery, 1997; Richardson & Butler, 2012; Baum et al., 2020; Magnini et al., 2024).

Despite these insights, three gaps remain. First, existing research focuses predominantly on the antecedents of turnover and workforce instability rather than managerial responses once shortages affect operations. Second, limited evidence examines how workforce pressures and responses vary across hotel departments. Third, quantitative assessments are rarely combined with qualitative managerial evidence explaining how responses are interpreted and implemented.

To address these gaps, this study adopts a department-level mixed-method perspective, integrating survey evidence from hotel managers in Kazakhstan with qualitative insights from senior managers representing multiple international hospitality contexts.

3 | METHODOLOGY

This study used a mixed-methods design that combined quantitative survey data with qualitative interview evidence (Creswell & Plano Clark, 2017). The quantitative survey was conducted between 7 December 2025 and 28 March 2026 and included 70 hotel respondents in Kazakhstan. Participants occupied managerial and operational positions and had direct knowledge of hotel operations and workforce-related challenges.

The study used purposive sampling to recruit respondents with relevant practical experience in staffing conditions and workforce management. Given the exploratory scope of the study, the survey aimed to identify patterns and associations rather than produce nationally representative estimates for Kazakhstan's hospitality industry. The sample size was considered adequate for the descriptive, comparative, and correlational analyses applied in this exploratory study, including comparisons of perceived workforce shortages across hotel departments and examination of associations between workforce pressures and managerial responses. The findings should therefore be interpreted as exploratory rather than nationally representative.

The qualitative component comprised seven semi-structured interviews with senior hotel managers representing six national contexts. The interviews contextualized and interpreted the quantitative findings. Survey and interview data were analyzed separately and subsequently integrated during interpretation of the results.

The profile of survey respondents is presented in Table 1.

Table 1. Sample profile of respondents

Category	Subcategory	Frequency
Position	General/Senior Management	9
	HR Management	11
	Department/Functional Management	38
	Other Operational Roles	12
Hotel Category	3-star	12
	4-star	38
	5-star	19
	Other	1
Total respondents		70

Note: compiled by the authors

The authors developed the questionnaire specifically for this study, based on workforce factors identified in the hospitality and workforce-management literature. The questionnaire consisted of three groups of variables: workforce shortages across hotel departments, workforce pressures, and managerial responses to staffing challenges.

Before the main survey, the authors reviewed the questionnaire to assess the

clarity, logical sequence, and comprehensibility of the questions. No separate formal pilot study involving an independent group of respondents was conducted. Workforce shortage severity was assessed across five hotel departments: Front Office, Housekeeping, Food and Beverage Service, Kitchen, and Engineering. Respondents evaluated perceived staffing shortages using a five-point Likert-type scale ranging from 1 (no shortage) to 5 (severe shortage). Workforce pressures included low wages, migration, seasonality, burnout, and skill gaps. These factors were assessed using a five-point scale ranging from 1 (very low impact) to 5 (very high impact). Managerial responses included wage increases, the use of digital tools and automation, the hiring of migrant labour, and reductions in service scope. The reported frequency of these responses was measured using a five-point scale ranging from 1 (never used) to 5 (very frequently used).

Table 2 summarizes the variables included in the analysis.

Table 2. Measurement of key variables

Category	Variable	Description	Scale
Workforce shortages	FO_Deficit	Front office staffing shortage	1 = no shortage; 5 = severe
	HK_Deficit	Housekeeping staffing shortage	1 = no shortage; 5 = severe
	FNB_Deficit	Food and beverage staffing shortage	1 = no shortage; 5 = severe
	Kitchen_Deficit	Kitchen staffing shortage	1 = no shortage; 5 = severe
	Engineering_Deficit	Engineering staffing shortage	1 = no shortage; 5 = severe
Workforce pressures	Low_Wages	Impact of low wages	1 = very low; 5 = very high
	Migration	Impact of labour migration	1 = very low; 5 = very high
	Seasonality	Impact of seasonality	1 = very low; 5 = very high
	Burnout	Impact of burnout	1 = very low; 5 = very high
	Lack_Skills	Lack of qualified workforce	1 = very low; 5 = very high
Managerial responses	Wage_Increase	Use of wage increases	1 = never; 5 = very frequently
	Automation	Use of digital tools and automation	1 = never; 5 = very frequently
	Migrant_Labour	Hiring of migrant workers	1 = never; 5 = very frequently
	Reduced_Services	Reduction of service scope	1 = never; 5 = very frequently

Note: compiled by the authors

Seven semi-structured interviews were conducted online with senior hotel managers (E1–E7) from six national contexts. Participants were purposively selected based on their senior managerial roles, direct experience with hotel workforce and operational decisions, and accessibility through direct professional contact. Each participant was contacted individually, and the interviews lasted approximately 15–20 minutes. The interviews focused on workforce shortages, managerial responses, technological adaptation, and the perceived effectiveness of different strategies.

Following data collection, the interview material was reviewed and thematically coded to identify recurring patterns across participants. Related codes were subsequently grouped into broader themes concerning workforce pressures, man-

agerial responses, technology implementation, and operational adaptation. The qualitative analysis was used to contextualize and explain the quantitative survey findings rather than to serve as a separate basis for statistical inference. Quantitative and qualitative data were therefore analyzed separately and integrated during the interpretation of the findings. The participant profile is presented in Table 3.

Table 3. Profile of qualitative interview participants

Code	Country	Hotel category	Position	Hotel type
E1	Kazakhstan	4★	General Manager	Independent
E2	Serbia	4★	Hotel Manager	Independent
E3	Kazakhstan	4★	General Manager	Independent
E4	Cyprus	5★	General Manager	Casino Resort
E5	Turkey	5★	Hotel Director	International Chain
E6	Montenegro	5★	General Manager	Independent
E7	Russia	5★	General Manager	Independent

Interview participants were anonymized and identified using codes E1–E7.

Note: compiled by the authors

Descriptive statistics were used to summarize workforce shortages, workforce pressures, and managerial responses. Differences in perceived shortage severity across the five hotel departments were examined using the Friedman test, appropriate for repeated ordinal measurements from the same respondents. Spearman's rank correlations were used to assess associations between workforce pressures and managerial response strategies.

Interview data were analyzed thematically to identify recurring patterns related to workforce pressures and managerial responses. Quantitative and qualitative findings were analyzed separately and integrated during interpretation, with interview evidence used to contextualize the statistical results.

4 | RESULTS

The section presents the main results of the analysis of staff shortages in hotels, the factors exacerbating staffing problems, and the management measures implemented in response to them. First, the differences between individual hotel departments are examined, followed by the main staffing factors and the management strategies used. The results obtained are supplemented by an analysis of the statistical relationships between the indicators under consideration.

Descriptive results indicate that perceived workforce shortages varied across hotel departments. Housekeeping reported the highest shortage severity (M = 3.73, SD = 1.01), followed by food and beverage (M = 3.30, SD = 1.22), kitchen (M = 3.26, SD = 1.21), and front office (M = 3.07, SD = 1.36). Engineering showed the lowest perceived shortage level (M = 2.37, SD = 1.05). A Friedman test confirmed that shortage severity differed significantly across the five departments, $\chi^2(4) = 65.69$, $p < .001$. The results indicate that perceived workforce shortage severity is

not uniform across hotel departments. Descriptively, Housekeeping showed the highest staffing pressure, whereas engineering showed the lowest.

The descriptive statistics and overall test results are presented in Table 4.

Table 4. Workforce shortages by department (N = 70)

Department	Mean (M)	SD
Housekeeping	3.73	1.01
Food & Beverage	3.30	1.22
Kitchen	3.26	1.21
Front Office	3.07	1.36
Engineering	2.37	1.05

*Five-point Likert scale (1 = no shortage; 5 = severe shortage). Friedman test: $\chi^2(4) = 65.69$, $p < 0.001$

Note: compiled by the authors

Descriptive results indicate that respondents perceived several workforce pressures as relevant to hotel operations. Low wages and burnout received the highest mean scores (both M = 3.54), followed closely by lack of skills (M = 3.46). Migration showed a moderate perceived impact (M = 3.11), while seasonality received the lowest mean score (M = 2.91). The relatively similar scores for low wages, burnout, and lack of skills suggest that workforce instability is associated with a combination of compensation, employee well-being, and skill availability rather than with a single dominant pressure.

The descriptive results for the five workforce pressures are presented in Table 5.

Table 5. Workforce pressures (N = 70)

Workforce pressure	Mean (M)
Low wages	3.54
Burnout	3.54
Lack of skills	3.46
Migration	3.11
Seasonality	2.91

*Values represent mean scores on a five-point scale (1 = very low impact; 5 = very high impact)

Note: compiled by the authors

The descriptive results show clear differences in the reported frequency of managerial responses to workforce shortages. Wage increases were the most frequently reported strategy (M = 3.71), indicating greater reliance on compensation adjustments than on the other strategies examined. Digital tools and automation ranked second (M = 3.00), suggesting a moderate level of use as an operational response to workforce pressure. Hiring migrant labour was reported less frequently (M = 2.50), while reducing the scope of services was the least frequently reported strategy (M =

2.40). Overall, managers reported greater use of compensation and technological responses than migrant labour or service reduction.

The descriptive results for managerial response strategies are presented in Table 6.

Table 6. Managerial response strategies (N = 70)

Managerial Response	Mean (M)
Wage increase	3.71
Automation	3.00
Migrant labour	2.50
Reduced services	2.40

*Values represent mean scores on a five-point scale (1 = never used; 5 = very frequently used)

Note: compiled by the authors

Spearman's rank correlations were used to examine associations between perceived workforce shortage severity in each hotel department and the four managerial response strategies. The results reveal several department-specific associations. Front Office shortage severity was positively associated with wage increases (ρ = .367, p = .002) and automation (ρ = .241, p = .045). Housekeeping shortages showed the strongest association with automation (ρ = .412, p < .001). In Food and Beverage, shortage severity was positively associated with both wage increases (ρ = .309, p = .009) and automation (ρ = .329, p = .005), whereas Kitchen shortages were positively associated with migrant labour (ρ = .240, p = .045).

Engineering shortages were associated with automation (ρ = .289, p = .015), migrant labour (ρ = .349, p = .003), and reduced services (ρ = .300, p = .012). Other correlations were not statistically significant. Overall, the pattern of association between workforce shortages and managerial responses differed across hotel departments. The complete correlation results are presented in Table 7.

Table 7. Correlations between department-level workforce shortages and managerial responses (N = 70)

Department shortage	Wage increase	Automation	Migrant labour	Reduced services
Front Office	.367**	.241*	−.086	.099
Housekeeping	.184	.412**	.191	.224
Food & Beverage	.309**	.329**	.189	.154
Kitchen	.098	.211	.240*	.174
Engineering	.215	.289*	.349**	.300*

Note: compiled by the authors

Spearman's rank correlations were used to examine associations between the five workforce pressures and four managerial response strategies. The results reveal several distinct patterns in how reported workforce pressures are associated with managerial responses.

Burnout showed the strongest positive association with wage increases (ρ = .422, p < .001), while low wages were also positively associated with this response (ρ = .246, p = .040). Lack of skills was positively associated with automation (ρ = .337, p = .004). Migration was positively associated with automation (ρ = .247, p = .039), migrant labour (ρ = .329, p = .005), and reduced services (ρ = .303, p = .011). Seasonality showed its strongest association with reduced services (ρ = .417, p < .001).

These findings indicate that different workforce pressures are associated with different managerial responses. Compensation adjustments are primarily associated with burnout and wage-related pressure, whereas skill shortages are associated with greater use of automation. Migration and seasonality show different response patterns, including migrant labour and service adjustment. The complete correlation results are presented in Table 8.

Table 8. Correlations between workforce pressures and managerial responses (N = 70)

Workforce pressure	Wage increase	Automation	Migrant labour	Reduced services
Low wages	.246*	.126	−.109	−.048
Migration	−.056	.247*	.329**	.303*
Seasonality	.127	.004	.134	.417**
Burnout	.422**	−.039	.112	.080
Lack of skills	.066	.337**	.194	.105

Note: compiled by the authors

The results obtained show that management measures in the hospitality business depend on the nature of personnel constraints and cannot be considered universal for all situations. More pronounced burnout and low levels of remuneration are primarily associated with the use of compensatory measures, while a shortage of qualified staff is linked to a more active use of automation. Migration processes and seasonality, in turn, are associated with the use of more flexible forms of adaptation, including the recruitment of migrants and changes in the volume of services provided.

From a business perspective, this means that the talent shortage affects not only personnel management but also operational decisions, cost structure, and technology selection. For hotels, rising wages increase staffing costs, automation requires additional investments, and a reduction in the volume of services may affect revenue and service quality. Therefore, managing the talent shortage should be considered part of the hotel's overall economic strategy, aimed at maintaining operational stability, controlling costs, and preserving service quality in a context of limited labor supply.

5 | DISCUSSION

The findings show that workforce shortages in hotel operations are unevenly distributed across departments and are associated with different managerial responses. The Friedman test confirmed significant differences in perceived shortage

severity across the five departments, with Housekeeping reporting the highest level of staffing pressure and engineering the lowest. This supports the view that hospitality workforce instability should not be treated solely as an organization-wide problem, because operational units differ in workload intensity, skill requirements, service interaction, and opportunities for technological support. These findings are consistent with research emphasizing the structural and operational nature of hospitality workforce challenges (Baum et al., 2020; Magnini et al., 2024). Recent department-level evidence similarly shows substantial staffing shortages in Housekeeping, Front Office, and Food and Beverage operations, reinforcing the need to examine hotel workforce constraints at the operational-unit level rather than only at the organizational level (Kwon, 2025).

The survey results also show that workforce instability cannot be attributed to a single pressure. Low wages and burnout received the highest mean scores, followed closely by lack of skills, while migration and seasonality were less prominent. This pattern is consistent with the Job Demands–Resources perspective, according to which sustained job demands can contribute to exhaustion when sufficient organizational resources are unavailable (Bakker & Demerouti, 2007). In labour-intensive hospitality environments, staffing shortages may therefore create a reinforcing cycle in which increased workload contributes to burnout and further undermines workforce stability (Karatepe, 2013; Karatepe et al., 2021). Recent empirical evidence similarly identifies low pay, demanding working conditions, and limited career opportunities as important drivers of employee turnover in labour-intensive hospitality operations (Ntwakumba & Nyathela-Sunday, 2026). Recent hospitality research further shows that burnout is associated with stronger intentions to leave, while job and career satisfaction contribute to organizational commitment and retention, supporting the need to address workforce instability through broader employment conditions rather than compensation alone (Holmes et al., 2025).

Managerial responses also differed in their reported frequency. Wage increases were the most frequently used strategy, whereas automation showed moderate use and migrant labour and service reduction were less frequent. More importantly, the correlation analysis indicates that these responses are associated with specific workforce pressures rather than being uniformly applied. Burnout showed the strongest association with wage increases ($\rho = .422$, $p < .001$), while low wages were also positively associated with compensation adjustments. These findings suggest that managers may use compensation not only in response to wage competitiveness but also when broader workforce strain becomes more pronounced. However, compensation alone may provide only a partial response when staffing instability is also related to workload, exhaustion, and skill availability (Magnini et al., 2024).

A different pattern emerged for technology. Lack of skills was positively associated with automation ($\rho = .337$, $p = .004$), while department-level analysis showed that Housekeeping shortage severity had the strongest association with automation ($\rho = .412$, $p < .001$). Food and Beverage, Front Office, and Engineering shortages also showed positive associations with automation. These results

suggest that digital tools may be used selectively where staffing constraints create opportunities for technological support rather than as a universal substitute for labour. This interpretation is consistent with research suggesting that technology can complement constrained labour supply while the need for human skills and service interaction remains important (Yeoman & McMahon-Beattie, 2026).

The qualitative evidence provides additional context for this pattern. One general manager explained that "AI is introduced as a response to rising costs and staff shortages, especially in repetitive and time-sensitive processes" (E3). This observation suggests that technological adoption may be motivated by immediate operational pressures as well as longer-term innovation objectives. At the same time, managers emphasized that implementation can generate employee uncertainty. As one participant noted, "The initial reaction among employees was characterized by significant apprehension and fear, especially regarding job security" (E4). Such concerns are consistent with research showing that technological change can create job insecurity and uncertainty among hospitality employees (Vrontis et al., 2022; Chen & Cai, 2025).

Migration and seasonality showed another distinctive response pattern. Migration was positively associated with migrant labour, automation, and reduced services, while seasonality showed its strongest association with reduced services ($\rho = .417$, $p < .001$). These findings indicate that managers may adjust workforce and service configurations differently depending on the source of operational pressure. Rather than supporting a single preferred response to workforce shortages, the results point toward a portfolio of managerial strategies shaped by specific staffing conditions.

From an economic perspective, the identified relationships show that the staff shortage is directly linked to the choice of the resource utilization model for a hotel enterprise. Increasing wages increases current personnel costs, automation requires investment expenditures, and a reduction in the volume of services can affect revenue, so personnel decisions should be considered part of an overall strategy for managing costs and ensuring operational stability.

The interviews further suggest that the effectiveness of these strategies depends on how they are implemented. Several managers emphasized gradual implementation and communication when introducing technological change. One manager stated, "We deliberately plan a gradual, phased introduction of technology to avoid major disruptions" (E5). Another observed that "Technology has significantly eased daily workload, and staff have adapted quickly to these tools" (E6). Together, these accounts suggest that technology may become more acceptable when employees experience practical workload benefits and when implementation is managed progressively rather than imposed abruptly.

The qualitative findings also reinforce the continuing importance of human service delivery. As one manager explained, "Success depends on finding the right balance between technology and the human touch" (E4). This is particularly relevant in hospitality, where efficiency gains must coexist with interpersonal service expectations. Technology should therefore be understood as one component of

workforce adaptation rather than as a complete replacement for human labour.

Overall, the combined findings extend existing hospitality workforce research in two ways. First, they demonstrate that workforce pressure differs significantly across operational departments, supporting a more granular approach than organization-level assessments alone. Second, they show that specific workforce pressures are associated with different managerial responses. Compensation, automation, migrant labour, and service adjustment therefore appear to perform different roles depending on the operational problem managers face. The integration of survey and interview evidence suggests that effective workforce management requires a context-sensitive combination of financial, technological, and human-resource responses rather than reliance on a single intervention.

6 | CONCLUSION

This study examined workforce shortages and managerial responses in hotel operations from a department-level mixed-methods perspective. The findings demonstrate that workforce pressure is not uniformly distributed across hotel departments, with Housekeeping reporting the highest perceived shortage severity and Engineering the lowest. Low wages, burnout, and lack of skills emerged as the most prominent workforce pressures, while wage increases were the most frequently reported managerial response.

Beyond these descriptive patterns, the study shows that specific workforce pressures are associated with different managerial responses. Burnout and low-wage pressure were associated with compensation adjustments, skill shortages with automation, migration with several adaptive responses, and seasonality particularly with service reduction. Department-level correlations further demonstrate that the relationship between staffing pressure and managerial action varies across operational areas.

By combining quantitative evidence from hotel respondents in Kazakhstan with qualitative insights from senior managers in multiple international hospitality contexts, the study contributes to a more differentiated understanding of workforce management in hospitality. The findings indicate that workforce shortages should not be treated as a uniform organizational problem, as different departments face different staffing pressures and may require different combinations of managerial responses.

Compensation remains an important managerial instrument, particularly because wage increases were the most frequently reported response and were positively associated with both burnout and low-wage pressure. However, compensation alone is unlikely to provide a comprehensive response when workforce instability is also related to workload, employee well-being, and skill shortages.

Technology also appears to have a targeted role. The association between skill shortages and automation, together with department-level associations between automation and shortages in several operational areas, suggests that digital tools may be most useful when applied to specific processes where they can reduce repetitive workload or support constrained skill availability. At the same time, tech-

nological solutions should complement rather than replace the human element of hospitality service.

Finally, migration and seasonality require different managerial responses. The associations between migration and migrant labour, and between seasonality and reduced services, indicate that workforce strategies should reflect the source of staffing pressure. Overall, effective workforce management requires a flexible combination of compensation, workforce development, recruitment, technological support, and operational adaptation tailored to department-specific conditions.

7 | LIMITATIONS AND FUTURE RESEARCH

Several limitations should be considered when interpreting the findings. First, quantitative analysis is based on managerial perceptions rather than objective operational or financial indicators and may therefore be affected by perceptual bias. Second, cross-sectional design identifies associations but does not establish causal relationships between workforce pressures and managerial responses.

Third, the survey sample comprised 70 respondents from hotels in Kazakhstan and was obtained through purposive sampling. The findings should therefore be interpreted as exploratory patterns rather than nationally representative estimates. In addition, the questionnaire was developed specifically for this study and was not subjected to a separate formal pilot study prior to the main survey. The seven interviews broaden the contextual perspective by including senior managers from several international hospitality settings, but the qualitative sample remains limited and was intended primarily to support interpretation of the survey findings.

Future research could examine these relationships using larger and more diverse samples across countries and hotel segments. Longitudinal designs could determine whether workforce pressures and managerial responses change over time, while objective indicators such as turnover, vacancy duration, labour costs, absenteeism, and service performance could complement managerial perceptions. Future studies could also examine whether hotel category, organizational size, and department characteristics moderate the relationships identified in this study.

Finally, further research should examine how artificial intelligence and automation reshape workforce responses, particularly whether technological support reduces workload and skill constraints or creates new challenges related to employee acceptance, job insecurity, and human–technology collaboration. Recent hospitality research suggests that AI may affect employee well-being while also generating job insecurity and technostress, reinforcing the need to examine both the potential benefits and risks of technological change (Sharif et al., 2025).

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Regional and Socio-Demographic Disparities in Road Traffic Injury Outcomes in Kazakhstan

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Abstract
This study aims to assess regional and socio-demographic disparities in road traffic injury outcomes in Kazakhstan by examining accident incidence, victim distribution, and the severity of consequences across regions, gender and age groups, and road-user categories. The initial information base consisted of official statistical data from the Committee on Legal Statistics and Special Accounts and the Bureau of National Statistics for 2015-2025. The study used methods of descriptive statistics, comparative analysis, indexing of time series with the base year 2015 and normalization of the number of accidents per 100 thousand population. Additionally, the proportion of deaths among victims by region and socio-demographic groups was calculated. The results showed that the number of registered road accidents increased from 18,890 in 2015 to 36,146 in 2025 (+91.35%), and the number of injured increased from 24,055 to 49,220 (+104.6%), while the death toll decreased from 2,453 to 2,330 people. In 2025, the maximum frequency of road accidents was recorded in Almaty city (332 per 100,000 population), and the largest proportion of deaths was in the Turkestan region (14.6%); men accounted for 54.0% of all victims and 71.7% of deaths, while the proportion of deaths increased from 2.2% in the 0–17-year group to 8.4% among persons 60 years of age and older. The results indicate pronounced regional and socio-demographic heterogeneity in road traffic injuries and confirm the need for a differentiated approach to accident prevention that considers regional characteristics, the victim profile, and the potential consequences for human capital and labor potential.

KEYWORDS
Traffic Accident, Road Injury, Gender Disparity, Age Disparity, Regional Economy, Transport Economy, Transport Infrastructure

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1 | INTRODUCTION

Modern socio-economic development is increasingly assessed not only through economic growth indicators but also through population safety, quality of life, and protection against everyday risks. Preserving human life and health, reducing premature mortality, and preventing injuries are essential conditions for sustainable economic development and social well-being. From an economic perspective, injuries and premature deaths generate substantial direct and indirect costs, including healthcare expenditures, rehabilitation costs, productivity losses, reduced labour participation, and additional financial burdens on households and public budgets. These consequences extend beyond affected individuals and influence labour markets, human capital accumulation, and the broader socio-economic development of territories.

Road traffic injuries represent one of the most significant public safety challenges, with considerable social and economic implications. Their consequences include premature mortality, temporary or permanent loss of working capacity, reduced household income, and increased demand for healthcare and social protection services. Moreover, the economic burden of road traffic accidents (RTAs) is distributed unevenly across population groups and territories. Differences in the incidence and severity of road traffic injuries may contribute to existing socio-economic inequalities, particularly when economically active individuals experience serious injuries or when households face additional care responsibilities and income losses.

In this context, road safety should be seen not only as an issue of transport infrastructure and compliance with traffic regulations but also as an important component of socio-economic development. According to the World Health Organization (2026), approximately 1.16 million people die annually as a result of road traffic accidents. In Kazakhstan, annual economic losses associated with RTAs are estimated at approximately USD 7 billion (Karimov, 2025). Although this figure is an indicative estimate, it highlights the potential economic significance of road traffic safety for the country. Official statistics further demonstrate the growing scale of the problem: between 2015 and 2025, the number of registered road traffic accidents increased from 18,890 to 36,146, while the number of injured persons rose from 24,055 to 49,220 (Committee on Legal Statistics and Special Accounts, 2026). Such dynamics underline the importance of examining road traffic injuries not only in terms of public safety but also in relation to their potential implications for labour resources, healthcare expenditure, and economic sustainability.

An additional concern is the uneven geographical and socio-demographic distribution of road traffic injuries. Regional disparities may reflect differences in transport infrastructure, traffic intensity, population density, road management, and access to emergency medical services. From an economic perspective, these differences are particularly relevant because regions vary in their demographic composition, labour resources, and capacity to respond to the consequences of traffic accidents. Similarly, gender and age disparities have important socio-economic implications. Higher mortality and injury rates among men may affect the eco-

nomically active population. In contrast, injuries involving children and older people may increase household care responsibilities and demand for healthcare and social support. Consequently, the analysis of road traffic injuries across population groups provides an additional perspective for understanding the unequal distribution of social and economic burdens.

Despite the growing importance of road traffic safety, aggregate national indicators alone cannot adequately reflect differences in accident incidence and severity across regions and socio-demographic groups. Identifying these disparities is essential to develop targeted preventive measures, improve regional road safety strategies, and inform public resource allocation. Such an approach is particularly relevant for Kazakhstan, where substantial regional differences in population distribution and socio-economic conditions require territorially differentiated policy responses.

Therefore, this study aims to assess regional and socio-demographic disparities in road traffic injury outcomes in Kazakhstan by examining accident incidence, victim distribution, and the severity of consequences across regions, gender and age groups, and road-user categories. By identifying territories and population groups with the most adverse outcomes, the study contributes to a broader understanding of road traffic injuries as a socio-economic challenge. It provides an empirical basis for developing targeted road safety interventions and supporting more effective allocation of public resources.

2 | LITERATURE REVIEW

Social differences in health status, mortality, and exposure to various types of trauma are considered one of the manifestations of broader social inequality. The classical concept of social determinants of health emphasizes that population health is determined not only by individual characteristics and medical factors, but also by the conditions that shape differences in the likelihood of death, morbidity, and other adverse outcomes between social groups and territories (Marmot, 2005). Furthermore, Cubbin and Smith (2002), summarizing studies on socio-economic differences in injury rates, showed that injury frequency and severity can vary significantly between population groups. Laflamme and Diderichsen (2000) demonstrated that among children and young people, road injuries are more common in groups with a lower social status and in socially disadvantaged areas. Nantulya and Reich (2003) expanded this approach by examining road injuries through the lens of social inequality, both between countries and within individual countries.

Morency et al. (2012) examined the territorial aspect of social inequality in road safety in detail. In their study of road traffic injuries in the Auckland region, New Zealand, Hosking et al. (2013) identified pronounced socio-economic and geographical differences, with the most noticeable gradient among children and adults aged 25–64. In Noland et al. (2013), conducted at the level of small territorial units in New Jersey, the study also found a link between a territory's income level and the number of people injured in traffic accidents. Subsequently, DiMaggio (2015) applied spatio-temporal analysis to pedestrian and cyclist injuries in New

York City at the census-tract level. The study enabled identification of territories with elevated injury levels and assessment of the role of socio-economic and transport characteristics in shaping spatial differences.

The main feature of the gender dimension of inequality in road safety is the higher proportion of deaths among men (Sorenson, 2011; Hanna et al., 2006). According to The Global Burden of Diseases, Injuries, and Risk Factors Study, road traffic injuries are among the leading causes of death and disability among young men (James et al., 2020).

Gender differences among road traffic victims largely reflect differences in participation in road traffic. According to Granié et al. (2025), women are consistently less represented as drivers than men and are more often passengers and pedestrians. Men, as a rule, travel longer distances and are more prone to risky driving, which is accompanied by a higher incidence of road traffic injuries. Grdinić-Rakonjac and Pajković (2026) found that men exceed the speed limit more often, regardless of conditions and road type. Women generally comply more often with established speed limits, but they are also more likely to exceed the speed limit on highways with higher permitted limits (60-80 km/h). In the study by Amarasingha and Dissanayake (2014), logistic regression data for the state of Kansas examined factors related to injury severity among male and female drivers. Advanced age does not reduce the risky behavior of men, which persists even when they are pedestrians, which is why the mortality rate among people aged 70 and older is higher for men than for women (Cordellieri et al., 2024).

The age structure of the victims is equally important, with children and the elderly being the most vulnerable. For elderly pedestrians, the likelihood of a severe or fatal injury is higher at any collision speed (Niebuhr et al., 2016). According to Holland and Hill (2010), older women are more likely to be involved in traffic accidents as pedestrians. As they age, they make increasingly risky decisions and become less accurate in assessing their walking speed. Furthermore, Tom and Granié (2011) found a high mortality rate among men aged 24–54 who were pedestrians. For children, the situation is different: at low vehicle speeds, their risk is lower than that of other groups, but once a certain threshold is exceeded, it rises sharply and becomes higher than in other groups (Niebuhr et al., 2016). Children are involved in traffic accidents less frequently than older people. However, their mortality rate remains high because of unpredictable behavior and difficulty assessing road situations, especially when crossing roads and using bicycles, scooters, and other individual mobility options (Swedler et al., 2024).

On urban roads, young men face the highest risk of road traffic injuries, even though women of the same age are more likely to drive (González-Sánchez et al., 2021). Research into the causes of this risk explains that young men are more likely to engage in risky or aggressive driving (Rhodes & Pivik, 2011). Studies have found that men are more likely than women to drive under the influence of alcohol or drugs (Oviedo-Trespalacios & Scott-Parker, 2018). According to Zabihi et al. (2019), seat belt use among men is declining on urban roads. Older drivers, along with young men, also face a high risk of injury (Zwerling et al., 2005). The high risk of

traffic injuries among older drivers is attributed to age-related declines in cognitive and sensory abilities, longer reaction times, and a reduced ability to maintain a constant distance from the vehicle ahead (Cordellieri et al., 2024; Doroudgar et al., 2017).

In Kazakhstan, studies have examined differences in road traffic injuries by gender and age, but mainly in relation to specific territories, medical institutions, or mortality rates. Aubakirova et al. (2013) analyzed regional differences in mortality from road traffic accidents using statistical data for 2004–2010 and identified territories with the most unfavorable indicators. Ibrayev et al. (2019), examining road safety on roads of republican significance for 2016–2018, identified territorial heterogeneity in accident-rate dynamics. Myssayev et al. (2014), based on data from the Regional Center for Forensic Medicine in Semey for 2006–2010, examined the characteristics of mortality resulting from road traffic accidents. In turn, Abdrakhmanova et al. (2017), using official statistics for 2013–2015, identified regional differences in the frequency of traffic accidents and the severity of their consequences, including the specific features of accident and mortality rates in the city of Almaty.

Domestic studies have also examined the socio-demographic aspects of road traffic injuries, albeit in a more limited territorial and temporal context. For example, Buleshova et al. (2016) analyzed the epidemiological characteristics of injuries, including the distribution of victims by gender and age, based on data from medical institutions in Shymkent for 2012–2014. Igissinov et al. (2020), using statistical data from 1999–2018, applied regression analysis and exponential modeling to assess and predict mortality from road traffic accidents, paying attention to age and gender differences.

Thus, an analysis of international and domestic scientific literature shows that road traffic injuries are characterized by pronounced territorial and socio-demographic differentiation. International studies examine how a territory's socio-economic characteristics, transport infrastructure, gender, age, and behavioral factors affect injury and mortality rates. Kazakhstani studies have provided an important empirical basis for studying this problem; however, many of the reviewed works rely on earlier statistical periods, are limited to specific territories, or analyze only specific aspects of mortality and injury.

In this regard, there remains a need for an updated comprehensive assessment of road traffic injuries, which would make it possible to compare regional differences in the frequency of traffic accidents simultaneously, the structure of victims by gender, age, and role as a road user, as well as the severity of the recorded consequences. This study aims to fill this analytical gap based on official statistical data from Kazakhstan for 2015–2025. The results may broaden understanding of road traffic injuries as a socio-economic problem related to preserving human capital, territorial differences, and the need for targeted resource allocation in road safety.

3 | RESEARCH METHODS

The study is based on secondary official statistical data from the Committee for Legal Statistics and Special Records of the General Prosecutor's Office of the Republic of Kazakhstan and the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

The analysis was carried out at two levels. At the national level, the dynamics of road traffic accidents (RTAs), the number of fatalities and injuries over the period 2015–2025 were examined. To assess regional and socio-demographic differences, data from 2025 were used, covering 20 administrative-territorial units of Kazakhstan (17 regions and three cities of republican significance), as well as categories of victims by gender, age, and role as a road user.

The study's methodological basis included descriptive statistics, comparative analysis, time-series indexing, and indicator normalization. To assess the severity of the recorded consequences of traffic accidents, the study also calculated the proportion of fatal outcomes among victims. Table 1 presents the indicator system used in the study.

Table 1. Indicators and measurement units used in the study

Variable	Measurement	Unit	Period	Data source
Road traffic accidents	Absolute count	Accidents	2015–2025	Committee on Legal Statistics and Special Accounts
Injured persons	Absolute count	Persons	2015–2025	Committee on Legal Statistics and Special Accounts
Fatalities	Absolute count	Persons	2015–2025	Committee on Legal Statistics and Special Accounts
Total victims	Injured + fatalities	Persons	2025	Authors' calculations
Accidents per 100,000 population	Normalized rate	Per 100,000 population	2025	Committee on Legal Statistics and Special Accounts
Regional fatality proportion	Percentage	%	2025	Authors' calculations
Victims by sex	Count and share	Persons, %	2025	Committee on Legal Statistics and Special Accounts
Victims by age group	Count and share	Persons, %	2025	Committee on Legal Statistics and Special Accounts
Victims by road-user category	Count and share	Persons, %	2025	Committee on Legal Statistics and Special Accounts
Fatality proportion by socio-demographic group	Percentage	%	2025	Authors' calculations

Note: compiled by the authors based on Committee on Legal Statistics and Special Accounts (2026)

The dynamics of three key indicators – the number of traffic accidents, fatalities, and injuries were analyzed for the period 2015–2025. To assess the overall direction and scale of the changes, the percentage change between the initial (2015) and final (2025) years of the study period was calculated by formula (1):

$$Change\,(\%) = \frac{Value_t - Value_0}{Value_0} \times 100 \tag{1}$$

where:

$Value_t$ – the value of the indicator in the base year;

$Value_0$ – the value of the indicator in the final year of the study period.

Since the absolute values of the number of traffic accidents, fatalities, and injuries vary significantly in scale, a time series indexing method with a fixed base year (2015 = 100) was used to ensure their comparability. The index for each indicator was calculated using the formula (2):

$$Index_t = \frac{X_t}{X_{2015}} \times 100 \tag{2}$$

where:

X_t – the value of the corresponding indicator in year t;

X_{2015} – the value of this indicator in the base year.

Thus, the obtained indices were used to graphically compare the relative dynamics of the three indicators over the study period. Furthermore, to assess regional differences, absolute and normalized indicators of traffic accidents for 2025 were used. Because the administrative-territorial units of Kazakhstan differ significantly in population size, the absolute number of accidents does not allow for accurate comparison. For this reason, the number of registered accidents per 100,000 inhabitants was additionally calculated. The normalized accident rate for a specific region was calculated using formula (3):

$$Accident\ Rate_i = \frac{Accidents_i}{Population_i} \times 100,000 \tag{3}$$

where:

$Accidents_i$ – the number of traffic accidents registered in the region;

$Population_i$ – the population of the region.

This indicator was used to compare the recorded frequency of traffic accidents, adjusted for regional population. In addition, the severity of the recorded consequences of traffic accidents was assessed through the proportion of fatal outcomes among all victims in the respective region, calculated using formula (4):

$$Severity_i = \frac{Deaths_i}{Deaths_i + Injured_i} \times 100 \tag{4}$$

where:

$Deaths_i$ – the number of fatalities and injuries recorded in the region;

$Injured_i$ – the number of injuries recorded in the region; the number of fatalities and injuries recorded in the region.

The indicator reflects the proportion of fatalities among all registered fatalities and injuries and allows comparison across regions regardless of the absolute number of traffic accidents. However, it does not characterize the clinical severity of the injuries sustained.

To identify socio-demographic differences, the structure of the injured was analysed by gender, age, status as a minor, and role as a road user. For each group, the share in the total number of injured was calculated, and for men and women,

the severity of the consequences of traffic accidents was additionally assessed. This approach identifies differences in the structure and severity of consequences between individual socio-demographic groups without interpreting the obtained indicators as the individual probability of being involved in a traffic accident.

For each group, the structural share of injured was calculated using formula (5):

$$Group\ Share = \frac{Victims\ in\ group}{Total\ victims} \times 100 \tag{5}$$

where:

$Victims\ in\ group$ – the number of dead and injured persons belonging to group g;

$Total\ victims$ – the total number of dead and injured in road traffic accidents.

Using this formula, the proportion of minors (under 18 years of age) in the overall structure of victims was also calculated. In addition, to compare the severity of the recorded consequences of traffic accidents between socio-demographic groups, the proportion of fatal outcomes was calculated separately. The severity of the consequences was calculated separately for men and women using formula (5):

$$Gender\ Severity_g = \frac{Deaths_g}{Deaths_g + Injured_g} \times 100 \tag{6}$$

where:

$Deaths_g$ – the number of fatalities in the corresponding socio-demographic group;

$Injured_g$ – the category of victims by gender, age or role.

The calculated indicators were used to identify regional and socio-demographic differences in the structure of victims and the proportion of fatal outcomes. The obtained results were interpreted as characteristics of registered road traffic injuries, rather than as an individual probability of being involved in a traffic accident, since the study does not include data on the intensity of participation of individual population groups in road traffic.

4 | RESULTS

In the first stage of the study, we analyzed the dynamics of road traffic accidents in Kazakhstan for 2015–2025. The main focus was on changes in three key indicators: the number of registered traffic accidents, fatalities, and injured persons. Comparing these indicators makes it possible to assess not only the general trends in accident rates but also the scale of the consequences of road traffic injuries, which are important for preserving human capital and the socio-economic well-being of the population.

To ensure comparability across indicators with different absolute values, we used an indexing method with a fixed base year (2015 = 100). Figure 1 presents the resulting dynamics.

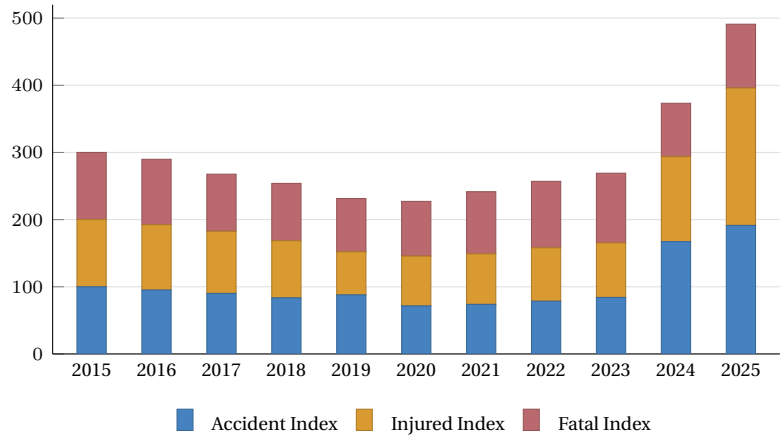


Figure 1. Dynamics of road traffic accidents, fatalities, and injuries in Kazakhstan for 2015–2025 (2015 = 100)

An analysis of the data presented in Figure 1 indicates divergent trends in the main road safety indicators. Over the study period, the number of registered road traffic accidents increased from 18,890 to 36,146 cases, representing a growth of 91.4%. Initially, the number of accidents declined, followed by a subsequent upward trend. The most pronounced increase was in 2024, when the number of registered accidents almost doubled from the previous year.

A similar upward trend was observed in the number of injured people. Between 2015 and 2025, this indicator increased from 24,055 to 49,220 people, representing a growth of 104.6%. During 2015–2019, the number of injured persons initially declined to 15,420 (by 35.9%), then rose substantially in subsequent years, reaching its highest recorded value in 2025.

Unlike the first two indicators, the number of fatalities showed a relatively small overall change between the study's initial and final years. From 2015 to 2025, fatalities decreased from 2,453 to 2,330 persons (by 5.0%). However, fatalities fluctuated considerably during this period. Between 2015 and 2019, the number of fatalities declined by 20.6%, reaching 1,947 people. Subsequently, the figure rose to 2,544 in 2023 (up 30.7% from 2019). In 2024, fatalities fell to 1,950 (down 23.3%), then rose to 2,330 in 2025 (up 19.5%).

Overall, the findings reveal divergent patterns in the dynamics of registered accidents, injuries, and fatalities. Despite a slight reduction in fatalities between 2015 and 2025, the substantial increase in road traffic accidents and injuries indicates that road traffic injuries remain a significant public safety concern. From a socio-economic perspective, these trends highlight the importance of preserving human capital, preventing potential losses of working capacity, and reducing the burden of road traffic injuries on the healthcare and social protection systems.

An analysis of the regional structure of traffic accidents in 2025 revealed significant territorial differences in registered incidents, fatalities, and injuries (Table 2).

Table 2. Regional differences in road traffic risk in Kazakhstan in 2025

Region	Accidents	Accidents per 100,000 population	Injured	Deaths	Fatality proportion among victims, %
Abai	1,134	188	1,632	95	5.5
Akmola	1,079	137	1,716	104	5.7
Aktobe	2,007	211	2,919	134	4.4
Almaty	3,708	238	5,613	374	6.2
Atyrau	1,880	264	2,689	96	3.4
West Kazakhstan	1,260	181	1,980	81	3.9
Zhambyl	2,042	167	3,071	205	6.3
Zhetisu	1,114	160	1,842	137	6.9
Karaganda	1,347	119	1,682	160	8.7
Kostanay	1,359	165	1,853	79	4.1
Kyzylorda	1,446	171	1,932	109	5.3
Mangystau	1,672	208	2,394	91	3.7
Pavlodar	1,151	153	1,663	81	4.6
North Kazakhstan	593	114	793	47	5.6
Turkistan	1,274	59	1,602	274	14.6
Ulytau	293	132	426	27	6.0
East Kazakhstan	1,271	176	1,843	61	3.2
Astana city	2,074	136	2,573	36	1.4
Almaty city	7,620	332	8,881	73	0.8
Shymkent city	1,822	145	2,116	66	3.0

Note: compiled by the authors

The largest absolute number of accidents was recorded in Almaty city (7,620 cases), Almaty region (3,708) and Astana city (2,074). The minimum values were observed in Ulytau (293), North Kazakhstan (593), and Akmola (1,079) regions. In terms of the number of deaths, the highest rates were registered in Almaty (374 people), Turkestan (274) and Zhambyl (205) regions. The lowest numbers of deaths were recorded in Ulytau region (27), Astana city (36), and North Kazakhstan region (47). Similar territorial differences are observed in the number of injured. The maximum values were registered in Almaty city (8,881 people), Almaty (5,613) and Zhambyl (3,071) regions. The minimum figures were recorded in the Ulytau (426), North Kazakhstan (793), and Turkestan (1,602) regions.

Thus, a high frequency of road accidents does not necessarily accompany a high proportion of deaths. This is most clearly shown when comparing Almaty city and the Turkestan region: Almaty city is characterized by the maximum frequency of registered road accidents (332 per 100,000 population), but the minimum proportion of deaths (0.8%), whereas in the Turkestan region, with the minimum frequency of accidents (59 per 100,000), this indicator reaches 14.6%.

These differences are socio-economically important, since road accidents can affect not only the healthcare system but also regional labor resources and business activities. A high frequency of accidents can lead to temporary disability, worker absences, additional costs for households and organizations, and an increased burden on transport and medical infrastructure. For businesses, road safety is especially important in industries related to road transportation, logistics, trade, construction, and employee mobility, where traffic accidents can cause downtime, delivery delays, and higher operating costs.

An analysis of the socio-demographic structure of the victims revealed marked

differences in gender, age, and the role of a road user. In 2025, men accounted for 54.0% of all road accident victims, while women accounted for 46.0%. However, the differences are significantly magnified when considering deaths: men accounted for 71.7% of all deaths, while women accounted for 28.3%. The proportion of deaths among male victims was 6.0%, which is more than twice as high as the corresponding figure among women (see Table 3).

Table 3. Gender differences in road traffic injury outcomes in 2025

Sex	Total victims	Injured	Deaths
Men	27843	26172	1671
Women	23707	23048	659

Note: compiled by the authors

The identified gender differences are of socio-economic importance, since a higher proportion of deaths among men potentially affects labor and human capital. However, the available data do not allow us to directly assess the loss of employment or labor productivity, since the study does not include information on the labor status, profession, or economic activity of those affected.

The age structure also shows significant differences (Table 4).

Table 4. Age and road-user profile of road traffic victims in Kazakhstan in 2025

Category	Total victims	Injured	Deaths	Share of total victims, %	Fatality proportion among victims, %
Age group					
0–17 years	12,732	12,446	286	24.7	2.2
18–20 years	4,085	3,975	110	7.9	2.7
21–29 years	9,117	8,763	354	17.7	3.9
30–39 years	9,365	8,951	414	18.2	4.4
40–49 years	6,489	6,092	397	12.6	6.1
50–59 years	4,777	4,429	348	9.3	7.3
60 years and older	4,985	4,564	421	9.7	8.4
Road-user category					
Drivers	10,602	9,907	695	20.6	6.6
Pedestrians	21,481	20,719	762	41.7	3.5
Passengers	19,478	18,604	874	37.8	4.5

Note: compiled by the authors

The largest proportion of victims are children aged 0-17 years (24.7%), as well as groups aged 30-39 years (18.2%) and 21-29 years (17.7%). At the same time, the proportion of deaths increases consistently with age: from 2.2% among children under 18 to 7.3% in the 50-59 age group and 8.4% among people aged 60 and older. At the same time, people aged 60+ account for only 9.7% of all victims, but 18.1% of all deaths, which indicates more severe consequences of road accidents for the older age group.

Collectively, the 18-59 age groups account for about 65.6% of all victims and 69.7% of deaths. Because this age range largely covers the economically active part

of the population, the high concentration of severe road-accident consequences in these ages can have broader effects on human capital, labor supply, and household economic well-being. At the same time, these indicators should not be interpreted as a direct assessment of labor losses, since the statistics used do not include victims' labor status.

An analysis of road-accident victims by gender and road-user role revealed additional differences in the structure and severity of the consequences (Table 5).

Table 5. Sex and road-user profile of road traffic victims in Kazakhstan in 2025

Road-user category	Men				Women			
	total victims	injured	deaths	fatality proportion, %	total victims	injured	deaths	fatality proportion, %
Drivers	8,674	8,025	649	7.5	1,928	1,882	46	2.4
Passengers	7,359	6,902	457	6.2	12,119	11,702	417	3.4
Pedestrians	11,820	11,254	566	4.8	9,661	9,465	196	2.0
Total	27,853	26,181	1,672	6.0	23,708	23,049	659	2.8

Note: compiled by the authors

The most pronounced gender differences are observed among drivers. Men make up about 82% of injured drivers, and the proportion of deaths among them reaches 7.5% compared to 2.4% among women. Among pedestrians, the numerical advantage of men is much weaker, but the proportion of deaths among men (4.8%) is more than twice as high as the corresponding figure among women (2.0%). On the contrary, among passengers, many victims are women (about 62%), however, in this category, the proportion of deaths among men is higher – 6.2% versus 3.4%.

These results are important from the perspective of preserving human capital and labor potential. The concentration of more severe consequences among male drivers is especially noticeable and may be significant for areas related to road transport, logistics, and passenger and cargo transportation. However, the data used does not allow us to distinguish between professional and personal trips, so direct conclusions about business losses require additional information.

5 | DISCUSSION

The results indicate a significant increase in registered accidents and injuries, with a relatively stable long-term mortality rate. This indicates the need for a comprehensive assessment of road safety that considers not only the number of accidents, but also the victim profile and the severity of their consequences.

International studies show that mortality due to road accidents may vary between urban and rural areas, including due to differences in speed, distance to medical care, and transport infrastructure (Ryb et al., 2012). However, the results of this study do not allow this conclusion to be extended directly to Kazakhstan, since the statistics do not include a separate distribution of victims by urban and rural areas.. Therefore, this factor should be considered a possible direction for further analysis.

The data also show pronounced gender differences. Men make up 54.0% of all victims, but they account for 71.7% of all deaths. The gender gap among drivers is particularly noticeable: about 82% of affected drivers are men, and the death rate among them is 7.5% versus 2.4% among women. These results align with international studies linking more severe road-accident outcomes among men to differences in road behavior, including a higher propensity for speeding and other risky driving (Granié et al., 2025; Grdinić-Rakonjac & Pajković, 2026).

Age analysis also revealed marked differences. The largest proportion of victims is among children under 18 years of age, while the proportion of deaths increases consistently with age and reaches its maximum among people 60 years and older. This pattern aligns with findings showing that older road users are more vulnerable to the severe consequences of collisions (Niebuhr et al., 2016). Behavioral factors and the ability to assess traffic conditions can play an important role for children, especially pedestrians and cyclists (Swedler et al., 2024).

The results confirm the need for a differentiated approach to road safety policy. In regions with a high frequency of accidents, accident prevention, traffic flow management, and infrastructure improvement may be a priority. In regions with a relatively low frequency of accidents but a high proportion of deaths, special attention should focus on reducing the severity of consequences, improving access to emergency medical care, and reducing response time. This approach can support more targeted allocation of public resources and reduce socio-economic losses associated with road injuries.

The study's main limitation is its reliance on aggregated official statistical data. The available database does not include information on injury severity, the intensity of participation of various population groups in traffic, victims' labor status, trip purpose, the state of road infrastructure, or the timing of emergency medical care. In addition, the analysis is descriptive and does not allow establishing causal relationships between socio-demographic characteristics and accident outcomes. Further research should supplement the analysis with indicators of transport exposure, road infrastructure characteristics, accessibility of medical care, and regional socio-economic parameters.

6 | CONCLUSION

The study aimed to assess regional and socio-demographic differences in road traffic injuries in Kazakhstan based on indicators of accident frequency, victim composition, and severity of consequences, and to identify territories and population groups with the most unfavorable characteristics. An analysis of official statistical data for 2015-2025 showed that, despite an overall increase in registered accidents and injuries, mortality dynamics were significantly less pronounced. This confirms the need to consider road safety not only through the number of accidents, but also through the severity of their consequences.

The regional analysis revealed significant differences between the territories. A high proportion of deaths did not always accompany the high frequency of reported accidents. The most noticeable contrast was between Almaty and the

Turkestan region: Almaty had the highest frequency of road accidents per 100,000 population but one of the lowest proportions of deaths, whereas the Turkestan region had a relatively low accident frequency but significantly higher severity of consequences. This indicates the need for a differentiated approach to road safety measures that consider regional specifics.

Socio-demographic analysis also showed marked differences. Men accounted for slightly more than half of all the victims, but they accounted for a significantly larger proportion of the dead. With age, the severity of the consequences increased consistently, reaching maximum values among people 60 years and older. At the same time, a significant proportion of the injured and dead were in age groups, largely covering the economically active population. According to the role of road users, pedestrians were the most numerous category, while the highest proportion of deaths was observed among drivers.

The results allow us to consider road traffic injuries not only as a transport safety problem, but also as a factor affecting the preservation of human capital, labor potential, and the socio-economic sustainability of regions. To improve the effectiveness of preventive measures, it is necessary to consider not only the accident rate but also the victims' demographic structure, the severity of the consequences, and regional differences. However, the study is limited to aggregated statistical data, which does not include information on injury severity, victims' employment status, traffic conditions, or the availability of emergency medical care. Further research may focus on these factors.

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