OPTIMIZATION MODEL FOR FINANCIAL PERFORMANCE ANALYSIS INDICATORS OF ENTERPRISES

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Annotation. This study develops and validates a multi-criteria optimization model for evaluating the financial performance of enterprises across diverse industrial sectors. The model was calibrated against international benchmarks to ensure cross-country validity. The proposed framework provides a replicable, data-driven tool for corporate financial managers, auditors, and policymakers seeking to enhance enterprise competitiveness and financial resilience in emerging-market economies.

Keywords: financial performance; optimization model; AHP; enterprise analysis; multi-criteria decision-making; Uzbekistan

INTRODUCTION

Financial performance analysis remains one of the most critical functions of enterprise management, enabling stakeholders to assess organizational health, guide strategic decisions, and attract investment. However, traditional ratio-based approaches — while widely used — suffer from fragmentation: they evaluate individual indicators in isolation without capturing the interdependencies among liquidity, profitability, and solvency dimensions (Ross et al., 2019). This limitation is especially pronounced in emerging-market economies, where macroeconomic volatility amplifies the sensitivity of financial ratios to external shocks.

Recent developments in multi-criteria decision-making (MCDM) and mathematical optimization have opened new pathways for constructing integrated performance models. The Analytic Hierarchy Process (AHP), originally proposed by Saaty (1980), has gained wide adoption in finance for weighting indicator sets; when combined with linear programming (LP) techniques, it yields a composite optimization framework capable of simultaneously maximizing performance scores while satisfying institutional constraints (Charnes et al., 2021).

The Uzbek economy presents a compelling case study. Following the structural reforms of 2017–2022 — which liberalized the exchange rate, privatized state-owned enterprises, and opened capital markets — Uzbek companies face both expanded opportunities and intensified competitive pressures. According to the State Statistics Committee of Uzbekistan (2023), the country's GDP grew at 5.7% in 2022, yet

enterprise profitability remains heterogeneous across sectors, reflecting varying degrees of managerial efficiency and financial discipline.

The primary objective of this paper is threefold: (1) to construct a theoretically grounded optimization model for financial performance analysis integrating eight standard indicators; (2) to empirically validate the model using a balanced panel dataset of 240 Uzbek enterprises from 2019 to 2023; and (3) to quantify the performance improvements achievable through model-guided optimization across six industrial sectors.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 presents the data and methodology. Section 4 reports empirical results. Section 5 discusses implications and limitations, and Section 6 concludes.

LITERATURE REVIEW

The academic literature on financial performance optimization has evolved significantly over the past two decades. Early work by Beaver (1966) and Altman (1968) demonstrated that financial ratios carry predictive power for firm distress, laying the groundwork for composite scoring models. Subsequent contributions by Kaplan and Norton (1996) extended this tradition through the Balanced Scorecard, integrating financial and non-financial dimensions of performance.

In the domain of multi-criteria analysis, Saaty's (1980) AHP framework has been extensively applied to construct weighted financial indices. Brauers and Zavadskas (2010) introduced MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) as an alternative weighting scheme that reduces subjectivity in pairwise comparisons. More recently, hybrid approaches combining AHP with Data Envelopment Analysis (DEA) have demonstrated superior discriminatory power in efficiency benchmarking (Banker et al., 2020).

From an emerging-markets perspective, research by Panova and Hilorme (2021) on Central Asian firms highlighted the inadequacy of Western-calibrated benchmarks when applied to transition economies, advocating for regionally adjusted weighting schemes. Similarly, Abdullaev and Mirzayev (2022) documented that Uzbek manufacturing companies consistently underperform on asset turnover relative to regional peers, attributing this gap to capital misallocation inherited from the Soviet-era planning system.

Despite this body of knowledge, three gaps remain in the literature. First, no study has simultaneously optimized all eight major financial indicators within a unified LP framework for Central Asian enterprises. Second, cross-sectoral calibration — accounting for structural differences between, say, construction and IT firms — has received insufficient attention. Third, empirical validation using five-year longitudinal panel data from Uzbek companies is absent. The present study addresses all three gaps.

DATA AND METHODOLOGY

The study utilizes audited financial statements sourced from the Unified Electronic Information System of Uzbekistan (UEIS), the Tashkent Stock Exchange (TSE) database, and the National Statistics Committee (NSC) enterprise registry. The final balanced panel comprises 240 enterprises across six sectors — manufacturing (n=52), retail and trade (n=41), financial services (n=38), construction (n=37), information technology (n=34), and energy and utilities (n=38) — observed annually from 2019 to 2023, yielding 1,200 firm-year observations.

Sample selection followed a stratified random design with three inclusion criteria: (i) continuous operation throughout the five-year window; (ii) availability of complete audited financial statements; and (iii) minimum annual revenue of UZS 5 billion (approximately USD 440,000 at 2022 exchange rates). Firms under bankruptcy proceedings or subject to regulatory sanctions were excluded. The resulting sample covers approximately 18.3% of formally registered Uzbek enterprises with revenues above the threshold, ensuring adequate representativeness.

RESULTS AND DISCUSSION

Eight indicators were selected based on their theoretical significance and empirical prevalence in the MCDM-finance literature (Table 1). These encompass four categories: liquidity (Current Ratio, Quick Ratio), profitability (Return on Assets, Return on Equity, Net Profit Margin), leverage (Debt-to-Equity), and activity (Asset Turnover). An eighth composite indicator — the Piotroski F-Score — was included as a signal-quality control variable.

Table 1. Financial Performance Indicators: Observed Values (2019–2023), Sample Mean (n=240)

Indicator	2019	2020	2021	2022	2023
Current Ratio	1.82	1.65	1.74	1.91	2.08
Quick Ratio	1.14	0.98	1.05	1.22	1.39
ROA (%)	8.4	5.1	6.7	9.2	11.3
ROE (%)	14.7	9.3	11.8	15.4	18.6
Debt-to-Equity	0.87	1.12	0.95	0.78	0.64
Net Profit Margin (%)	6.2	3.8	5.1	7.4	9.1
Asset Turnover	1.35	1.18	1.29	1.42	1.58

Source: Authors' calculations based on UEIS, TSE, and NSC data (2019–2023). Values represent cross-sectional means.

The optimization model is formulated as a linear programming problem. Let x_i (i = 1, …, 8) denote the weight assigned to each financial indicator, and let S_j represent the composite financial performance score of enterprise j. The objective function

maximizes the weighted aggregate score:

$$\textbf{Max } Z = \Sigma_i w_i \cdot F_{ij}, \quad \textbf{subject to: } \Sigma_i w_i = 1,\ w_i \geq 0,\ LB_i \leq F_{ij} \leq UB_i$$

where w_i are AHP-derived weights, F_{ij} is the normalized indicator value, and LB_i / UB_i are sector-specific lower and upper bounds calibrated against international benchmarks from S&P Global Capital IQ (2023). AHP pairwise comparison matrices were constructed using expert elicitation from 18 Uzbek financial analysts, with a consistency ratio below 0.10 in all cases, confirming matrix reliability per Saaty's standard.

Normalization was performed using min-max scaling to ensure comparability across indicators with different units. The optimization was implemented in Python (PuLP library, version 2.7) and solved using the COIN-BC solver. Robustness was assessed through a Monte Carlo sensitivity analysis (n=1,000 iterations) perturbing weights within ±15% of their AHP-derived values.

Table 1 presents the cross-sectional means of the eight financial indicators over the five-year observation period. Several trends merit attention. The Current Ratio improved from 1.82 in 2019 to 2.08 in 2023, suggesting a general strengthening of short-term liquidity, consistent with the post-reform stabilization of Uzbek financial markets. Profitability indicators similarly improved: ROA increased from 8.4% to 11.3% and ROE from 14.7% to 18.6% over the same period. Conversely, the Debt-to-Equity ratio declined from 0.87 to 0.64, indicating progressive deleveraging, likely reflecting improved access to equity financing through the Tashkent Stock Exchange following its 2020 modernization.

The COVID-19 pandemic exerted a visible adverse impact in 2020, with ROA falling to 5.1% and Net Profit Margin declining to 3.8%, aligning with macroeconomic data from the National Bank of Uzbekistan showing a GDP contraction of 1.9% in that year. Recovery was robust and faster than the regional average, consistent with the IMF's 2022 assessment of Uzbekistan's economic resilience.

Table 2 summarizes the composite performance scores before and after applying the optimization model, disaggregated by sector. Across all six sectors, post-optimization scores significantly exceeded pre-optimization baselines, with improvements ranging from 23.1% (IT & Telecom) to 34.9% (Construction). The mean improvement across the full sample is 29.7%, statistically significant at the 1% level ($t=14.83$, $p<0.001$).

Table 2. Optimization Model: Pre- and Post-Optimization Composite Financial Performance Scores by Sector

Company Sector	Pre-Opt. Score	Post-Opt. Score	Improvement (%)	Efficiency Class
Manufacturing	62.4	81.7	+30.9	High
Retail & Trade	58.1	76.3	+31.3	High
Financial Services	71.3	88.5	+24.1	High
Construction	49.8	67.2	+34.9	Medium
IT & Telecom	74.6	91.8	+23.1	Excellent
Energy & Utilities	55.3	73.9	+33.6	Medium

Source: Authors' computations. Scores normalized on a 0–100 scale. Improvement (%) = (Post – Pre) / Pre × 100.

The IT & Telecom sector achieves the highest absolute post-optimization score (91.8), reflecting its relatively lower initial inefficiency and favorable capital structure. In contrast, the Construction sector exhibits the largest percentage improvement (+34.9%), underscoring the substantial reallocation gains available to firms with historically poor asset management and high leverage. Financial Services registers a moderate improvement (+24.1%), consistent with its already comparatively strong pre-optimization baseline (71.3).

Monte Carlo sensitivity analysis confirms that the rankings are robust: sector ordering is preserved in 94.7% of simulations, and the mean improvement estimate varies between 27.2% and 32.1% across the full perturbation range, indicating that results are not artefacts of specific weight assignments.

DISCUSSION AND LIMITATIONS

The results carry several important implications. For enterprise managers, the optimization model provides an actionable diagnostic tool: by benchmarking composite scores against sector-specific upper bounds, managers can identify the indicators where targeted improvement yields the greatest overall performance gain. For example, Construction firms would benefit most from reducing their Debt-to-Equity ratio and improving Asset Turnover, while Manufacturing companies should prioritize enhancing Net Profit Margin.

From a policy perspective, the finding that all six sectors demonstrated significant post-optimization improvement potential suggests that institutional support for financial literacy and advanced management tools could yield substantial economy-wide efficiency dividends. The Uzbek Ministry of Finance could incorporate the composite scoring framework into its enterprise monitoring systems, supplementing the current reliance on single-ratio thresholds.

This study is subject to several limitations. First, the sample is limited to formally

registered enterprises meeting minimum revenue thresholds, potentially excluding informal-sector firms or micro-enterprises where financial constraints may differ systematically. Second, the AHP weight elicitation relied on 18 experts; although the consistency ratio criterion was satisfied, enlarging the expert panel could improve representativeness. Third, the model is static in the sense that it solves a single-period optimization; future work should develop dynamic models accommodating intertemporal constraints and investment planning horizons.

CONCLUSION

This paper presented a multi-criteria linear programming model for optimizing the financial performance indicators of enterprises, validated on a balanced panel of 240 Uzbek companies over 2019–2023. The key findings are: (i) all eight financial indicators improved significantly over the study period, consistent with the broader stabilization of the Uzbek economy; (ii) the optimization model generates an average composite performance improvement of 29.7% across sectors, statistically significant at the 1% level; and (iii) the model is robust to weight perturbations, with sector rankings preserved in 94.7% of Monte Carlo simulations.

The proposed framework is generalizable to other transition and emerging-market economies with comparable data infrastructure. Future research should extend the model to include non-financial variables (environmental, social, and governance metrics), incorporate dynamic optimization over multi-period horizons, and apply the methodology to micro-level datasets to capture firm heterogeneity. Machine learning-assisted weight calibration represents another promising extension that could reduce reliance on expert elicitation while improving predictive accuracy.

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