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AN EIGHT-SUBSYSTEM ARCHITECTURE FOR MANAGING INDUSTRIAL ENTERPRISE EFFICIENCY: DESIGN PRINCIPLES AND EMPIRICAL VALIDATION

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Abstract

Contemporary organisational and economic management theory has moved beyond single-loop control frameworks toward architectures that integrate multiple management functions into coherent, mutually reinforcing systems. For resource-intensive industrial enterprises operating in commodity-exposed markets, this integration imperative is particularly acute: the fragmentation of efficiency, resource, and quality management into separate organisational silos generates information gaps, duplicated functions, and — most critically — an inability to identify and systematically realise internal performance reserves. The design challenge is thus not merely to add new management instruments, but to construct an architecture in which their interaction produces emergent capabilities that no single instrument could deliver in isolation.

This paper presents an eight-subsystem organisational and economic mechanism developed and validated at JSC Dekhkanabad Kaliy Zavodi (DKZ) — the sole potash fertiliser producer in Uzbekistan and Central Asia. The enterprise's operating context — extreme commodity price volatility, significant capacity underutilisation (61.3% in 2025), and a post-privatisation governance transition — creates a demanding testing environment for any management architecture. The mechanism was developed in response to six systemic deficiencies identified

in the incumbent management system: reactive ex-post control, weak alignment between motivation systems and resource efficiency metrics, insufficient digitalisation of cost accounting, fragmentation of efficiency and quality management contours, financial results dominated by price cycles rather than internal improvements, and absence of a formalised reserve identification system [1].

The eight subsystems are organised into three functional tiers. The first tier — strategic orientation — comprises the goal-setting and strategy alignment subsystem (Subsystem I), which translates enterprise-level objectives into measurable operational targets, and the input parameter monitoring subsystem (Subsystem II), which provides real-time digital tracking of resource consumption across all production stages. The second tier — analytical processing — encompasses the diagnostic and benchmarking subsystem (Subsystem III), which compares current performance against international best-practice frontiers, and the analytical processing subsystem (Subsystem IV), which applies formal decomposition methods to separate price-driven from operationally-driven performance contributions. The third tier — implementation and control — includes the decision-making subsystem (Subsystem V), operating under scenario planning with commodity price hedging instruments; the motivation and incentive subsystem (Subsystem VI), which aligns personnel KPIs with resource efficiency targets rather than revenue or profit metrics; the anticipatory control subsystem (Subsystem VII), which shifts the control locus from ex-post variance analysis to pre-emptive deviation management; and the results assessment and loop closure subsystem (Subsystem VIII), which feeds assessment outcomes back into the goal-setting tier to initiate the next management cycle [2].

The closed-loop feedback architecture — connecting Subsystem VIII back to Subsystem I — is the mechanism's defining structural feature. It transforms what would otherwise be a sequential management process into a self-correcting system capable of continuous improvement. The digital integration layer spanning Subsystems II, III, and IV enables real-time information flow that reduces the decision lag between performance signal detection and management response, a critical capability in markets where commodity price cycles can shift enterprise financial performance by an order of magnitude within a single year.

Empirical validation employed the composite performance index I(t), constructed through min-max normalisation of six efficiency indicators with differentiated weights. Calculated across 2016–2025, I(t) rose from 0.031 to 0.559, with a conjunctural peak of 0.901 in 2022 driven primarily by the global potash price spike. The internal resource index $I_{vn}(t)$ — derived from the four least price-sensitive indicators and designed to track genuine operational progress — demonstrated a more stable recovery trajectory: 0.482 in 2023, 0.578 in 2024, and 0.631 in 2025, confirming that real operational improvements were occurring even as financial metrics fluctuated with commodity prices [3].

The mechanism's economic effect was quantified through an additive model with conservatively calibrated parameters. The guaranteed annual effect from deploying the digital monitoring layer (Subsystem II) and the KPI-aligned motivation system (Subsystem VI) amounts to UZS 498.2 million, comprising UZS 253.2 million from energy saving, UZS 164.0 million from material saving, and UZS 81.0 million from managerial process optimisation. At an estimated one-off implementation cost of UZS 500 million, the payback period is 1.18 years. Under full mechanism deployment, the annual effect range extends to UZS 1,807.4 million [4].

The eight-subsystem architecture is designed for transferability: its modular structure allows individual subsystems to be implemented sequentially rather than simultaneously, and the weighting scheme of I(t) can be recalibrated to reflect the specific cost structure and production technology of different enterprises. The framework is therefore applicable beyond the potash sector to any resource-intensive industrial enterprise in which the separation of external price effects from genuine internal efficiency improvements constitutes a management priority.

Keywords: organisational and economic mechanism, eight-subsystem architecture, closed-loop management, industrial efficiency, composite performance index, resource efficiency, potash industry, Uzbekistan, digitalisation, KPI alignment.

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