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INTEGRATED MULTI-LEVEL ASSESSMENT OF INNOVATION AND INVESTMENT EFFICIENCY IN SPORTS EQUIPMENT MANUFACTURING BASED ON EVIDENCE FROM UZBEKISTAN

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Abstract. *This article develops a decision-oriented, multilevel framework for assessing innovation and investment efficiency in Uzbekistan's sports equipment manufacturing industry. The objective is to connect regional innovation conditions with enterprise technology readiness and competitiveness while explicitly accounting for safety testing, standards conformity, and digital traceability. Using 2024 official statistics for fourteen territorial units, seven indicators were normalized and aggregated with Shannon entropy weights. At the enterprise level, a five-block, nineteen-indicator techno-indicative matrix was applied to LB SPORT and MAGNA SPORT; a six-block analytic hierarchy process (AHP) model was used to examine competitiveness priorities. Regional index values were 0.194 for Andijan, ranked sixth, and 0.020 for Fergana, ranked fourteenth. Innovation expenditure per capita received the highest entropy weight, 0.261, whereas fixed-capital investment per capita received 0.089. Calibrated enterprise technology scores were 0.551 and 0.497, respectively, with conditional targets of 0.737 and 0.673 by 2030. The AHP comparisons exhibited a consistency ratio near 0.003, while modeled competitiveness scores reached 61.6 and 52.5 points. The framework distinguishes external innovation constraints from internal organizational capabilities and links diagnostic gaps to investment priorities in digital production, product testing, and certification. Importantly, the baseline enterprise scores rely on public profiles and explicitly modeled parameters rather than audited operating records; the 2030 indicators are illustrative targets, not realized outcomes. The proposed method supports investment screening and managerial monitoring but requires subsequent validation using company-level records, independent expert judgments, and repeated observations over time. Its principal contribution is original sector-specific integration rather than the invention of new weighting algorithms.*

Keywords: *innovation; investment; manufacturing; sports; entropy; hierarchy; technology; conformity; competitiveness; Uzbekistan.*

INTRODUCTION

The international market for sports equipment increasingly rewards reliable, safe and certifiable products rather than production capacity alone. For domestic manufacturers, the economic value of an investment depends on whether machinery is accompanied by appropriate design competence, product testing, coordinated subcontractors, digital records and after-sales learning. The fourth edition of the Oslo Manual defines innovation beyond research expenditure, encompassing new or improved products and business processes brought into use (OECD/Eurostat, 2018). The international testing framework for stationary training equipment makes product-specific compliance a distinct operational requirement (ISO, 2024).

Uzbekistan offers a revealing policy setting. The dissertation-based trade evidence reports

approximately USD 32.0 million of imports and USD 0.24 million of exports under HS 9506 for 2024; imports for HS 950691 reached about USD 16.56 million (WITS/UN Comtrade, 2024; Xamraqulov, 2026). This gap makes import substitution and export upgrading important, but it cannot be interpreted solely as a lack of installed machinery. Moreover, some product lines sold by domestic manufacturers are classified outside HS 9506. The publicly reported approximately USD 3 million of exports associated with a sports-equipment producer must therefore not be compared directly with HS 9506 exports without matching customs categories (President of Uzbekistan, 2026).

A further challenge arises from regional differentiation. Innovation expenditures, skilled labour, fixed-capital investment and manufacturing productivity are distributed unevenly across Uzbekistan. The two case manufacturers are located in Baliqchi district of Andijan region; their local institutional environment is shared, but production technology, enterprise organization and market orientation differ. When investment assessment is confined to static financial ratios, managers may overlook the extent to which costly equipment is actually integrated into processes and the readiness of products to pass safety tests and enter new markets.

Recent research makes the distinction between acquiring a technology and using it effectively particularly relevant. The World Bank emphasizes that the technology gap among developing-country firms is driven not only by adoption but also by varying sophistication across business functions (Cirera et al., 2022). A manufacturing study associates digital technologies with stronger operational performance through organizational learning and complementary practices (Sunder & Prashar, 2024). Evidence from manufacturing firms likewise indicates that digitalization management mediates technological performance (Zaman, 2025). These findings motivate a framework that gives managerial capabilities independent visibility alongside capital purchases.

This article aims to develop and interpret a multilevel, decision-oriented method for assessing innovation and investment efficiency in the sports-equipment manufacturing sector. It addresses three measurable questions: which territorial indicators best differentiate the regional environment; how effectively the two case firms have integrated technological, digital and quality capabilities; and which priorities follow from combining the resulting diagnostics with a consistent competitiveness model. The object is sports-equipment manufacturing enterprises, and the subject is the methodological connection between innovation conditions, technology readiness and investment management. The originality lies in the industry-specific integration of established measurement methods, particularly the explicit treatment of conformity assessment, testing and operational traceability.

LITERATURE REVIEW

Three theoretical perspectives underpin the analysis. First, Schumpeter (1934) associates economic development with new combinations of products, processes and markets, while Lundvall (1992) places learning and relationships among institutions at the center of innovation systems. The Oslo Manual distinguishes product innovation from business-process innovation and thus provides a defensible vocabulary for including data systems and quality practices in the same analytical model as equipment renewal (OECD/Eurostat, 2018).

Second, measurement research shows the benefit and risks of aggregated scores. The information-theoretic principle introduced by Shannon (1948) provides the basis for entropy-based weighting, in which indicators with greater relative differentiation receive higher informational weights. Multi-criteria approaches then aggregate distinct criteria for managerial assessment (Zeleny, 1982). The analytic hierarchy process (AHP) formalizes pairwise comparisons and allows a consistency ratio to be computed (Saaty, 1980). Nevertheless, neither entropy nor AHP independently establishes a valid industry-specific list of indicators; even internally consistent weights may embed subjective assumptions. The OECD/JRC handbook therefore recommends transparent normalization, sensitivity testing and interpretive caution (OECD & JRC, 2008).

Third, studies of complementary capabilities explain why capital alone is not sufficient. Cohen and Levinthal (1990) describe absorptive capacity as the ability to recognize, assimilate and exploit

new knowledge. Kaplan and Norton (1992) argue for performance dashboards that extend beyond conventional financial metrics. From a more recent empirical perspective, manufacturing firms' ability to integrate digital tools with operational learning emerges as a central factor for performance (Sunder & Prashar, 2024; Zaman, 2025). Wen et al. (2024), using regional manufacturing data from China, additionally connect digitalization with green productivity, suggesting that resource efficiency deserves a distinct diagnostic block. At the policy level, the OECD (2021) identifies business-process integration and management capacity as major challenges in the digital transformation of smaller firms.

The proposed framework responds to limitations in both the measurement and management literatures. Porter (1990) places product quality and industry-supporting institutions within competitive advantage, but conventional competitiveness indicators do not necessarily reveal whether a producer's batches are traceable or whether product-test reports are available. International ISO requirements establish why some sports-equipment product categories face material safety obligations (ISO, 2024). Accordingly, the present application separates regional context from firm-level performance, includes technology and testing capabilities explicitly, and translates scores into investment and operational priorities. This is a methodological adaptation, not an assertion that entropy or AHP is a newly invented algorithm.

METHODOLOGY

The study was organized across three analytically separate levels. For 2024, a regional innovation–investment index was constructed from publicly reported indicators for 14 territorial units. A firm-level techno-indicative matrix was applied to LB SPORT LLC and MAGNA SPORT LLC in Andijan region using open enterprise profiles and modeled operating parameters. A six-block RIBOM-Sport competitiveness structure was then used to connect the diagnostics to managerial decisions. Data sources comprised Uzbek statistical publications, SIAT, public company and registry profiles, the official business report and the DSc dissertation calculations (Statistics Agency, 2025; President of Uzbekistan, 2026; Xamraqulov, 2026; WITS/UN Comtrade, 2024).

The regional and enterprise units were not pooled into one statistical regression or treated as causally interchangeable. Regional observations provide an external context indicator, while firm-level scores are managerial diagnostics. The 2025 enterprise scores are calibrated estimates from accessible information and declared assumptions, because audited company financial statements, ERP logs and full test records were unavailable. The 2030 figures are conditional targets and are not presented as achieved results. No independent expert questionnaire or experiment was conducted for the present article.

Seven benefit indicators were used: innovative output per capita; innovation expenditure per capita; research personnel per 10,000 persons; fixed-capital investment per capita; industrial output per worker; foreign investment and credits per capita; and implemented innovations per 100,000 persons. The raw values were transformed to the unit interval with cross-territorial min–max normalization. Shannon entropy and the composite index were calculated using the following definitions (Shannon, 1948; OECD & JRC, 2008):

$$z_{ij} = (x_{ij} - \min_i x_{ij}) / (\max_i x_{ij} - \min_i x_{ij})$$

$$p_{ij} = z_{ij} / \Sigma_i z_{ij} \; ; \quad E_j = -(1/\ln 14) \Sigma_i p_{ij} \ln(p_{ij})$$

$$w_j = (1 - E_j) / \Sigma_j (1 - E_j) \; ; \quad REI_i = \Sigma_j w_j z_{ij}$$

Here, i indexes regions and j indicators. A zero share contributes zero to p ln p by continuity. REI varies between zero and one. Entropy weights capture variation in the observed cross-section, rather than causal importance; an economically necessary variable can receive a low informational weight if its territorial variation is limited.

The technology integration score (TIS) was built from 19 indicators in five blocks: technological renewal (four indicators), digital integration (four), quality and standards conformity (four), innovative products (three), and resource efficiency (four). Negative indicators, including

equipment age, defect rate, energy intensity and the idea-to-market cycle, were reverse-normalized against fixed reference ranges, while positive indicators were normalized directly. Each block was formed by the mean of its indicators; the overall score was aggregated additively:

$$TIS = 0.24T + 0.22D + 0.20Q + 0.16I + 0.18R$$

The weights represent the proposed structure of the techno-indicative matrix. In its indicator classification, 0.38 of the total weight relates mainly to asset acquisition and 0.62 to utilization, coordination, compliance and innovative output. These numbers are design weights and were not estimated as regression coefficients. The threshold levels were defined as low for TIS below 0.50, intermediate for 0.50–0.69 and high for 0.70 or above; equal-weight calculations served as a sensitivity check.

A complementary six-block RIBOM-Sport model assessed innovation capability, investment activity, quality/conformity, digital production, market/export performance, and human capital/service. Saaty's pairwise-comparison procedure was used to obtain the criterion weights. With six criteria the consistency measures were defined as $CI = (\lambda max - 6)/5$ and $CR = CI/1.24$. The original dissertation comparison used $\lambda max \approx 6.018$, giving $CR \approx 0.003$ (Saaty, 1980; Xamraqulov, 2026). This indicates internal coherence, not independent expert validation. The index was formed from weighted standardized criterion values multiplied by 100. Outcomes were checked against the dissertation results, with scenario targets explicitly separated from the modeled baselines.

ANALYSIS AND RESULTS

The 2024 entropy index places Andijan sixth, Namangan ninth and Fergana fourteenth among the 14 territorial units. The highest displayed entropy weight is 0.261 for innovation expenditure per capita, compared with 0.089 for investment in fixed capital per capital.

Table 1.

Entropy weights and selected regional indicators, 2024

Indicator	Weight	Andijan	Namangan	Fergana
Innovative output per capita, thousand UZS	0.190	4,882.4	50.4	155.9
Innovation expenditure per capita, thousand UZS	0.261	169.0	14.0	27.1
R&D personnel per 10,000 persons	0.147	6.95	4.02	5.20
Fixed-capital investment per capita, million UZS	0.089	8.45	17.69	5.30
Industrial output per employed person, million UZS	0.132	67.7	27.3	29.3
Foreign investment and credits per capita, million UZS	0.089	6.58	14.56	3.23
Implemented innovations per 100,000 persons	0.093	8.0	5.2	4.0
Regional environment index (rank)	1.000	0.194 (6)	0.102 (9)	0.020 (14)

The leading territorial scores in the dissertation sample are 0.749 for Tashkent city and 0.679 for Navoi region. These values summarize cross-sectional differences and should not be interpreted as causal effects of individual indicators.

Table 2.

Technology integration scores: calibrated 2025 values and conditional 2030 targets

Block	Weight	LB 2025	MAGNA 2025	LB 2030	MAGNA 2030
Technological renewal	0.24	0.68	0.52	0.82	0.70
Digital integration	0.22	0.45	0.49	0.72	0.68
Quality and standards	0.20	0.62	0.58	0.84	0.80

conformity					
Innovative products	0.16	0.38	0.31	0.55	0.48
Resource efficiency	0.18	0.58	0.55	0.70	0.66
Overall TIS	1.00	0.551	0.497	0.737	0.673

The 2025 overall TIS scores were 0.551 for LB SPORT and 0.497 for MAGNA SPORT. The lowest block scores were for innovative products (0.38 and 0.31) and digital integration (0.45 and 0.49). The respective conditional 2030 targets were 0.737 and 0.673. Under equal weights of 0.20 across the five blocks, the alternative 2025 scores were approximately 0.542 and 0.490; the ranking was unchanged.

Table 3.

AHP-supported RIBOM-Sport blocks and modeled 2025 competitiveness scores

Competitiveness block	AHP weight	LB SPORT 2025	MAGNA SPORT 2025
Innovation capability	0.222	0.58	0.50
Investment activity	0.151	0.70	0.52
Quality and conformity	0.209	0.60	0.60
Digital production	0.151	0.46	0.47
Market and exports	0.163	0.74	0.50
Human capital and service	0.105	0.64	0.55
RIBOM-Sport score (points)	≈1.000	61.6	52.5

The modeled RIBOM-Sport baseline scores were 61.6 points for LB SPORT and 52.5 points for MAGNA SPORT. Innovation capability held the largest AHP weight (0.222), followed by quality and conformity (0.209).

Figure 4.

Conceptual progression from regional diagnosis to investment decision

1. REGIONAL CONTEXT	2. ENTERPRISE DIAGNOSIS	3. MANAGEMENT RESPONSE
Entropy-weighted index of 14 territorial units	19-indicator technology integration matrix	RIBOM-Sport priorities, project screening
External innovation and finance conditions →	Technology, digital, quality and resource bottlenecks →	Fund, implement, test and monitor selected projects

Conditional 2030 competitiveness targets in the broader dissertation were 77.7 and 69.7 points, respectively; these were not realized outcomes.

DISCUSSION

The results indicate why a composite assessment of investment effectiveness in sports-equipment manufacturing must make organizational integration and conformity readiness visible. The entropy index gives innovation expenditure much greater informational weight than fixed-capital investment in the 2024 territorial cross-section; this does not prove that capital is unimportant. Rather, it indicates that different dimensions distinguish the 14 regions to different degrees. The finding is consistent with a literature in which innovative learning and complementary capabilities shape industrial performance (Lundvall, 1992; OECD/Eurostat, 2018; Cirera et al., 2022).

At the company level, technology acquisition and technology integration are not interchangeable concepts. LB SPORT's modeled technological-renewal block is relatively strong, but its digital and innovative-product blocks are weaker. The distinction echoes the operational-management literature emphasizing that digital technologies provide larger benefits when combined with organizational changes and continuous learning (Sunder & Prashar, 2024; Zaman, 2025). In a

distributed home-based production network, digital batch identifiers, work cards and inspection logs are plausible ways of connecting design decisions to output quality. Such options are proposed management responses, not field-tested impacts demonstrated by the present data.

The sector-specific significance of testing is central. Certain product categories face defined safety requirements; for example, ISO 20957-1:2024 sets general requirements for stationary indoor training equipment (ISO, 2024). Product conformity can operate as a threshold for procurement, competition use and some export opportunities. In such circumstances, a producer may report stronger equipment capacity while lacking the evidence of safety and quality needed to access buyers. RIBOM-Sport accordingly places quality/conformity immediately after innovation in the AHP priorities, although the comparisons reflect analytical judgments rather than an independent consensus.

The multilevel design avoids mixing distinct units of observation. A regional innovation index reports relative environmental differentiation; a firm-level technology index assesses operational attributes; a competitiveness score organizes strategic priorities. Combining these three numbers into a single regression would not identify a causal mechanism. Instead, the framework is best interpreted as a sequence of management decisions: determine external constraints, record internal technology gaps, prioritize investments and monitor subsequent operational changes. As stressed by the OECD/JRC approach to composite indicators, robustness checks and transparent normalization are essential for this interpretation (OECD & JRC, 2008).

Several limitations require attention. The regional comparison contains only one year of cross-sectional observations. Enterprise inputs rely on publicly accessible profiles and assumptions rather than audited financial, testing or digital production registries; thus numerical baselines may change when primary records become available. The AHP consistency ratio of approximately 0.003 tests the internal logic of the chosen comparisons, not whether external experts would agree. The model cannot establish that future targeted improvements will occur. A practical validation design would gather at least twelve consecutive quarters of enterprise-level KPI data, register product-testing outcomes, obtain independent pairwise comparisons and compare alternative normalization and weighting choices.

The managerial contribution is therefore conditional but actionable. A small manufacturer can use the block profile to justify a digital production register or a shared testing facility before investing in additional capacity. Financial institutions can link staged disbursement to documented milestones in QR traceability, product-conformity checks and quality records rather than to machinery delivery alone. Follow-up studies should measure whether such changes actually reduce rework, certification delays and unit costs under commercially realistic conditions.

CONCLUSION

The study presents an integrated, multilevel approach to assessing innovation and investment efficiency in sports-equipment manufacturing. Entropy-weighted regional assessment, a five-block techno-indicative matrix and the six-block RIBOM-Sport competitiveness model were linked in a decision sequence without conflating their respective units of analysis. The framework identifies differentiated regional innovation conditions and persistent enterprise weaknesses in digital integration and new-product capability, even when investment in physical assets is visible.

Its contribution is methodological adaptation to the industry's requirements for product safety, conformity, traceability and coordinated production. The proposed scores can support investment screening and enterprise diagnostics, but they do not demonstrate causal improvements or completed implementation. The next step is to test the framework against audited firm-level indicators and independent expert evaluations, then monitor performance prospectively as technology and testing systems are introduced.

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