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Article

Methodology for Calculating an Integral "Strategic Development Index" to Assess the Effectiveness of Implementing Long-Term Development Goals of Building Materials Manufacturing Enterprises

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Abstract: Purpose. The paper develops and tests a methodology for calculating an integral Strategic Development Index (SDI) that measures how far a building materials manufacturing enterprise has advanced towards the quantitative targets of its long-term development strategy and whether it is moving along the planned trajectory. Design/methodology/approach. A hierarchical composite indicator is built from 20 indicators grouped into five strategic dimensions: financial-economic, production-technological, market, innovation-investment and environmental-social (ESG). Indicators are normalised by goal-attainment against 2030 target values with bounded over-fulfilment; weights are obtained by a linear synthesis of Analytic Hierarchy Process (AHP) expert priorities and Shannon-entropy weights; sub-indices and the integral index are aggregated by weighted geometric means to limit compensability. A trajectory-conformity coefficient (actual SDI divided by the SDI of the planned path) and strategic momentum (compound annual growth of the SDI) complete the dynamic assessment. Robustness is tested by 10,000 Monte Carlo simulations of weights, the over-fulfilment cap and the aggregation rule, by one-at-a-time exclusion of dimensions and by comparison with TOPSIS. Findings. The methodology is demonstrated on an illustrative panel of five anonymised enterprises for 2020–2025. The AHP judgement matrix is consistent (CR = 0.003). In 2025 the SDI ranges from 0.512 to 0.854; three enterprises are ahead of their planned trajectory (by 2.2–10.4%), while one lags it by 23.5% and would reach its 2030 targets only around 2034 at its current momentum. Rankings are highly stable: the modal rank occurs in at least 99.7% of simulations, and Spearman correlation with arithmetic aggregation and with TOPSIS equals 1.00. The innovation-investment and ESG dimensions carry the highest discriminating information. Originality/value. Unlike benchmarking-type indices, the SDI is anchored to the enterprise's own strategic targets and to a planned time path, so it evaluates strategy execution rather than relative position. The index supports strategic control, early warning of deviations and the reallocation of investment between strategic dimensions in a sector undergoing rapid capacity growth and decarbonisation.

Keywords: strategic development index; composite indicator; strategy execution; building materials industry; cement; AHP; entropy weighting; goal attainment; sensitivity analysis; Uzbekistan.

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1. Introduction

1.1 Background and relevance

The building materials industry is a backbone of construction, housing and infrastructure investment, and in many emerging economies it has become one of the fastest-growing manufacturing branches. Uzbekistan is a telling example. According to the national Statistics Agency, large enterprises produced 9.08 million tonnes of cement in January–July 2024, 34.6% more than in the same period of 2023 [1]. Output in January–November 2024 reached 14.74 Mt against 11.17 Mt a year earlier and 10.79 Mt in the corresponding period of 2022 [2]. The country operated 38 cement enterprises with a combined capacity of 35.3 Mt per year in 2024, with expansion to 40.8 Mt expected by the year end [3]. This growth followed a presidential resolution of 2019 on accelerating the development of the building materials industry, which set targets for 2019–2025 that included doubling cement production [4], and it is now embedded in the national development strategy "Uzbekistan – 2030" [5].

Rapid capacity growth creates a specific managerial problem. Enterprises of the sector adopt long-term development programmes with ambitious targets for output, modernisation, export, product diversification, energy efficiency and, increasingly, decarbonisation. Cement alone accounts for about 7% of global anthropogenic CO_2 emissions [6], [7], and the industry roadmaps require deep cuts in clinker factor, fuel mix and energy intensity by 2050 [8], [9], [10]. Long-term goals therefore become multidimensional, partly conflicting and measured in different units. Managers, owners and public authorities need a single, transparent and reproducible measure that answers two questions: *how much* of the strategic target set has been achieved, and *whether* the enterprise is moving fast enough to meet the targets on time.

Three streams of literature are relevant. The first concerns strategic management and the control of strategy execution. Classic strategic planning theory [11], [12] defined long-term goals as the starting point of strategy, while Mintzberg [13] showed that intended strategies are only partly realised and that the gap between plan and outcome must be monitored continuously. The Balanced Scorecard translated strategy into a set of financial and non-financial measures [14], [15] and later linked them to strategy maps and operational reviews [16]. The performance measurement literature emphasised that measurement systems must be balanced, derived from strategy and dynamic [17], [18]. However, scorecards deliver a dashboard of separate measures rather than an integral judgement, and they offer no formal rule for combining dimensions or for assessing progress against the time path of the strategy.

The second stream addresses the construction of composite indicators. The OECD–JRC handbook codified the ten-step procedure of theoretical framing, indicator selection, imputation, multivariate analysis, normalisation, weighting, aggregation, uncertainty and sensitivity analysis, and presentation [19]. Subsequent reviews show that weighting and aggregation remain the most contested steps [20]. Subjective weights such as those produced by the Analytic Hierarchy Process [21], [22] capture strategic priorities but are sensitive to expert bias; objective weights based on information entropy [23], [24] or on contrast and correlation [25] reflect the discriminating power of the data but may contradict the conceptual importance of dimensions. Integrated subjective–objective schemes were therefore proposed [26], [27], and recent studies still refine the balance between expert opinion and entropy [28], [29]. On aggregation, linear additive rules imply full compensability, i.e. a deficit in one dimension can be offset by a surplus in another, which is inconsistent with the logic of balanced development; geometric aggregation reduces compensability and satisfies desirable measurement properties [30], [31]. Saisana et al. [32] and Saltelli [33] argued that uncertainty and sensitivity analysis is an indispensable part of any composite indicator.

The third stream applies multi-criteria methods to enterprise evaluation. Combined AHP–entropy schemes have been used to evaluate logistics enterprises [34], and distance-

based methods such as TOPSIS [35] are widely applied for ranking companies and energy options [36]. These applications, however, typically produce *relative* scores, a ranking of enterprises against one another or against the best observed unit, rather than an *absolute* assessment of progress towards an enterprise's own strategic targets. They are also mostly static, comparing units at one point in time.

The review reveals a gap between strategic management, which needs a goal-anchored and dynamic measure of strategy execution, and composite-indicator practice, which mostly produces relative, static scores. For building materials enterprises the gap is aggravated by the coexistence of capacity-growth targets with energy and emission targets that pull in different directions. The aim of this study is to develop a methodology for calculating an integral Strategic Development Index that (i) is anchored to the enterprise's long-term target values; (ii) combines expert strategic priorities with the information content of the data; (iii) limits compensation between strategic dimensions; (iv) evaluates conformity with the planned trajectory and the momentum of development; and (v) is accompanied by a formal robustness assessment.

The paper contributes in three ways. Methodologically, it proposes a goal-attainment normalisation with bounded over-fulfilment and a trajectory-conformity coefficient that together turn a composite indicator into an instrument of strategic control. Empirically, it demonstrates the full calculation, from the indicator system to positioning, on a panel of building materials enterprises. Practically, it provides a classification scale and a strategic positioning matrix that managers and regulators can use directly. The remainder of the paper is organised following the IMRAD structure: Section 2 describes the materials and methods, Section 3 reports the results, Section 4 discusses them, and Section 5 concludes.

2. Materials and Methods

2.1 Research design

The methodology follows the OECD–JRC sequence adapted to the evaluation of strategy execution at enterprise level. It consists of seven stages: (1) decomposition of the long-term strategy into strategic dimensions and measurable indicators with 2030 target values; (2) data collection for the baseline year and subsequent reporting years; (3) goal-attainment normalisation; (4) determination of combined weights; (5) aggregation into sub-indices and the integral SDI; (6) dynamic assessment through the planned trajectory and strategic momentum; and (7) robustness and validity testing. The conceptual framework is shown in Figure 1.

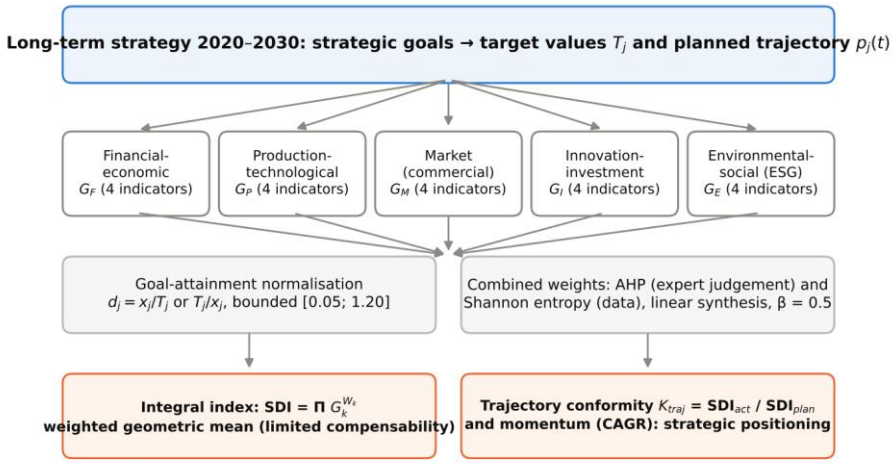


Figure 1. Conceptual framework of the Strategic Development Index (SDI). Source: developed by the authors.

2.2 System of indicators

Indicators were selected according to five criteria: relevance to the strategic goals typical of building materials producers; measurability from standard financial, technical

and sustainability reporting; sensitivity to managerial decisions; absence of duplication; and availability of an explicit target value in the strategy. The resulting system contains 20 indicators, four in each of five dimensions (Table 1). The financial-economic dimension (F) reflects profitability, financial stability and leverage. The production-technological dimension (P) captures capacity use, labour productivity, energy efficiency and the share of modern dry-process or automated capacity, which is decisive for energy consumption in cement and ceramics. The market dimension (M) covers sales growth, market share, export orientation and the share of high value-added products such as special cements, dry mixes and composite materials. The innovation-investment dimension (I) measures investment intensity, R&D spending, product renewal and digital maturity. The environmental-social dimension (E) contains CO_2 intensity, the substitution rate of alternative fuels and supplementary cementitious materials (SCM), occupational safety and staff turnover, consistent with industry decarbonisation roadmaps.

Table 1. System of indicators of the Strategic Development Index and 2030 target values

Code	Indicator	Unit	Type	Target 2030
F1	Return on assets	%	S	12
F2	EBITDA margin	%	S	28
F3	Equity-to-assets ratio	%	S	60
F4	Net debt / EBITDA	times	D	1.5
P1	Capacity utilisation	%	S	90
P2	Labour productivity	th. USD/empl.	S	95
P3	Specific energy consumption	GJ/t	D	3.1
P4	Share of modern (dry-process/automated) capacity	%	S	95
M1	Real sales volume index (2020=100)	index	S	180
M2	Domestic market share	%	S	15
M3	Export share of sales	%	S	20
M4	Share of high value-added products	%	S	40
I1	Investment intensity (CAPEX / sales)	%	S	12
I2	R&D and innovation expenditure / sales	%	S	2
I3	Share of new products in sales	%	S	18
I4	Digital maturity score	0–100	S	80
E1	CO2 intensity	kg CO2/t	D	560
E2	Alternative fuels & SCM substitution rate	%	S	30
E3	Lost-time injury frequency rate	per 1 mln h	D	0.8
E4	Staff turnover	%	D	8

Note: S = stimulant (higher is better); D = destimulant (lower is better). Groups: F1–F4 financial-economic; P1–P4 production-technological; M1–M4 market; I1–I4 innovation-investment; E1–E4 environmental-social. Target values are those of the illustrative strategy used in the case application and must be replaced by each enterprise's approved strategic targets. Source: developed by the authors.

Goal-attainment normalisation

Let $x_{ij}(t)$ be the value of indicator j for enterprise i in year t and T_{ij} its strategic target value for the horizon year t_H = 2030. Instead of min–max or z-score normalisation, which

compare enterprises with each other, the SDI uses a goal-attainment ratio that compares each enterprise with its own target:

$$d_{ij}(t) = \min\{ \max[x_{ij}(t) / T_{ij} ; \delta] ; c \} \quad \text{for stimulants,} \tag{1}$$

$$d_{ij}(t) = \min\{ \max[T_{ij} / x_{ij}(t) ; \delta] ; c \} \quad \text{for destimulants,} \tag{2}$$

where $\delta = 0.05$ is a technical floor that keeps the geometric mean defined, and $c = 1.20$ is a cap on over-fulfilment. The cap prevents an enterprise from compensating the failure of one strategic goal by excessive over-achievement of another, a known weakness of unbounded ratios. Thus $d_{ij} = 1$ means that the 2030 target has been fully achieved, and $d_{ij} = 0.7$ means that 70% of the target level has been attained. The ratio scale is meaningful because all indicators are measured on ratio scales with a natural zero.

2.3 Determination of weights

Subjective weights (AHP). Experts compare the five strategic dimensions pairwise on Saaty's 1–9 scale. The priority vector is the normalised principal eigenvector of the judgement matrix **A**, and consistency is checked by

$$CI = (\lambda_{max} - n)/(n - 1), \quad CR = CI / RI, \tag{3}$$

where λ_{max} is the principal eigenvalue, $n = 5$ and RI = 1.12 is the random index. Judgements are accepted if CR < 0.10. Within each dimension, local priorities v_j were assigned by the same panel; the subjective weight of indicator j in dimension k is $w_j^s = W_k^{AHP} \cdot v_j$. In the case application the judgement matrix reflects a strategy in which financial sustainability is the prerequisite of development and production and innovation goals are its main levers (Table 2).

Table 2. AHP pairwise comparison matrix of strategic dimensions and resulting priorities

Dimension	F	P	M	I	E	Priority W^{AHP}
F – Financial-economic	1	2	3	2	3	0.369
P – Production-technological	1/2	1	2	1	2	0.206
M – Market	1/3	1/2	1	1/2	1	0.109
I – Innovation-investment	1/2	1	2	1	2	0.206
E – Environmental-social (ESG)	1/3	1/2	1	1/2	1	0.109

Note: $\lambda_{max} = 5.013$; CI = 0.0033; CR = 0.0030 < 0.10, so the judgements are consistent.
Source: authors' calculations.

Objective weights (entropy). For each indicator the share of observation s (enterprise–year) in the pooled sample of N observations is $p_{sj} = d_{sj} / \Sigma_s d_{sj}$. The Shannon entropy and the resulting weights are

$$e_j = -(1/\ln N) \Sigma_s p_{sj} \ln p_{sj}, \quad w_j^o = (1 - e_j) / \Sigma_j(1 - e_j), \tag{4}$$

so that indicators with greater dispersion of attainment, and hence greater power to discriminate between enterprises and periods, receive higher weights.

Combined weights. Following the integrated subjective–objective approach, the final weights are a linear synthesis

$$w_j = \beta\, w_j^s + (1 - \beta)\, w_j^o, \quad \beta = 0.5, \tag{5}$$

which gives equal standing to strategic priorities and to data information. A linear rather than multiplicative synthesis was chosen because the multiplicative rule amplified entropy differences excessively in preliminary runs, assigning almost half of the total weight to one dimension. The dimension weight is $W_k = \Sigma_{j \in k} w_j$, and the local weight of indicator j inside its dimension is w_j / W_k. The sensitivity of results to β and to all weights is examined in Section 2.7.

2.4 Aggregation

Sub-indices and the integral index are calculated as weighted geometric means:

$$G_{ik}(t) = \Pi_{j \in k}\, d_{ij}(t)^{\,w_j / W_k}, \tag{6}$$

$$SDI_i(t) = \Pi_{k=1..5} G_{ik}(t)^{W_\{k}\}. \quad (7)$$

Because the weights sum to one and d_{ij} is bounded, SDI ∈ [0.05; 1.20], and SDI = 1 corresponds to full attainment of the 2030 strategy. Geometric aggregation penalises unbalanced development: an enterprise with uneven attainment across dimensions obtains a lower SDI than one with the same arithmetic mean but balanced attainment. This property is consistent with the strategic logic that long-term goals form an interdependent system.

2.5 Dynamic assessment and classification

A static SDI shows the level of target attainment but not whether the pace of execution is adequate. The strategy is therefore also represented by a planned trajectory. For each indicator the planned value in year t is interpolated between the baseline $x_{ij}(t_0)$ and the target:

$$p_{ij}(t) = x_{ij}(t_0) + [T_{ij} - x_{ij}(t_0)] \cdot (t - t_0) / (t_H - t_0), \quad (8)$$

with $t_0 = 2020$. Linear interpolation is the default; where the strategy specifies intermediate milestones (for example, the commissioning year of a new kiln line), the milestone path replaces the linear one. Applying Equations (1)–(7) to $p_{ij}(t)$ gives the planned index $SDI^{plan}{}_i(t)$, and the trajectory-conformity coefficient and strategic momentum are

$$K^{traj}{}_i(t) = SDI_i(t) / SDI^{plan}{}_i(t), \quad (9)$$

$$\mu_i = [SDI_i(t) / SDI_i(t_0)]^{1/(t - t_\{0})} - 1, \quad \tau_i = \ln(1/SDI_i(t)) / \ln(1 + \mu_i). \quad (10)$$

$K^{traj} > 1$ means that the enterprise is ahead of its strategic schedule; μ is the average annual growth of the SDI; τ is the number of years needed to reach full attainment if the current momentum persists, which can be compared with the remaining strategic horizon. The level of strategic development is classified on the scale in Table 3, and the combination of level and conformity forms a strategic positioning matrix with four quadrants.

Table 3. Scale for interpreting the Strategic Development Index

SDI range	Level of strategic development	Interpretation for strategic control
≥ 0.85	High	Strategy largely implemented; focus on target revision and new long-term goals
0.70 – 0.849	Sustainable	Implementation on course; maintain resource allocation, monitor weak dimensions
0.55 – 0.699	Moderate	Partial implementation; corrective measures in lagging dimensions needed
< 0.55	Low	Strategic risk; revision of action plan, investment programme or targets required

Note: thresholds follow the conventional quartile-type gradation of attainment and should be recalibrated as the strategic horizon approaches. Source: developed by the authors.

2.6 Robustness and validity testing

Following Saisana et al. and Greco et al., four checks were performed. (1) *Internal consistency* of each dimension was assessed with Cronbach's α and pairwise Pearson correlations on the pooled panel. (2) *Uncertainty analysis*: 10,000 Monte Carlo runs simultaneously perturbed the weights (Dirichlet distribution centred on the combined weights with concentration parameter 60, corresponding to a coefficient of variation of roughly 35–60% for individual indicator weights), the over-fulfilment cap $c \sim U(1.0; 1.4)$ and the aggregation rule (geometric with probability 0.75, arithmetic with probability 0.25). For each run the SDI and ranks were stored. (3) *One-at-a-time exclusion* removed each dimension in turn and recomputed the index. (4) *Method comparison*: the SDI ranking was compared with the arithmetic composite and with the TOPSIS closeness coefficient using Spearman's ϱ.

2.7 Data

The methodology is demonstrated on an illustrative panel of five building materials enterprises, labelled E1–E5, for 2020–2025 (30 enterprise–year observations, 600 indicator values). The panel is anonymised and model-generated: baseline values were calibrated to ranges typical of mid-sized cement and building-materials producers, and annual values were generated from enterprise-specific execution paces, dimension-specific strengths and weaknesses, an indicator-level heterogeneity term, a common cost shock in 2022 (energy and logistics prices) and random noise. The enterprises were given deliberately different profiles: E4 a fast and balanced implementer, E2 a strong incumbent with a high baseline, E1 an accelerating moderniser with weak ESG performance, E3 a low-baseline catch-up producer that is fast in production modernisation but weak in markets and ESG, and E5 a slow implementer. The purpose of the panel is to demonstrate the calculation procedure and the diagnostic power of the index; when the methodology is applied to an actual enterprise, its own reporting data and approved strategic targets should be used. All calculations were performed in Python (NumPy, SciPy) and are fully reproducible.

3. Results

3.1 Weights of indicators and strategic dimensions

The AHP priorities place the financial-economic dimension first (W^{AHP} = 0.369), followed by production and innovation (0.206 each) and by market and ESG (0.109 each). The entropy analysis gives a markedly different picture (Table 4, Figure 2a). The highest objective weights belong to R&D intensity I2 (0.151), the share of new products I3 (0.119), the export share M3 (0.113) and the substitution rate of alternative fuels and SCM E2 (0.102), i.e. to the strategic goals where enterprises diverge most. Conversely, CO_2 intensity (E1), capacity utilisation (P1) and specific energy consumption (P3) show low dispersion of attainment (entropy close to 1) and hence little discriminating power, although they remain strategically important.

After synthesis, the innovation-investment dimension receives the largest weight (W_I = 0.294), followed by financial-economic (0.230), market (0.169), ESG (0.163) and production-technological (0.144). The combined scheme thus corrects two biases at once: it prevents the experts' emphasis on finance from dominating the index, and it prevents entropy from over-weighting innovation indicators whose dispersion is partly due to low baselines. The five most influential indicators are I2, I3, F1, M3 and I1, which together carry 39.0% of the total weight (Figure 2b).

Table 4. Subjective, objective and combined weights of indicators

Code	w^s (AHP)	Entropy e_j	w^o (entropy)	w (combined)	Local weight in group
F1	0.111	0.9932	0.033	0.072	0.312
F2	0.111	0.9967	0.016	0.063	0.275
F3	0.074	0.9984	0.008	0.041	0.177
F4	0.074	0.9928	0.035	0.054	0.236
P1	0.052	0.9989	0.005	0.028	0.197
P2	0.062	0.9924	0.037	0.049	0.344
P3	0.052	0.9994	0.003	0.027	0.190
P4	0.041	0.9926	0.036	0.039	0.269
M1	0.027	0.9973	0.013	0.020	0.119
M2	0.033	0.9907	0.045	0.039	0.230
M3	0.027	0.9768	0.113	0.070	0.414
M4	0.022	0.9880	0.058	0.040	0.237
I1	0.062	0.9848	0.073	0.068	0.230

Code	w^s (AHP)	Entropy e_j	w^o (entropy)	w (combined)	Local weight in group
I2	0.041	0.9689	0.151	0.096	0.326
I3	0.052	0.9755	0.119	0.085	0.289
I4	0.052	0.9918	0.040	0.046	0.155
E1	0.038	0.9995	0.002	0.020	0.124
E2	0.027	0.9788	0.102	0.065	0.398
E3	0.022	0.9846	0.074	0.048	0.295
E4	0.022	0.9922	0.038	0.030	0.183

Source: authors' calculations.

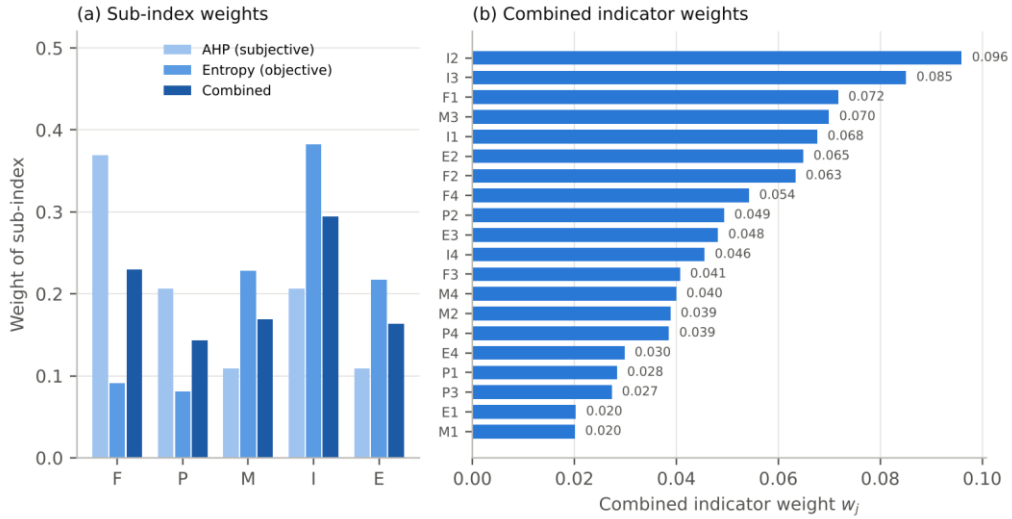


Figure 2. Weights of strategic dimensions under the AHP, entropy and combined schemes (a) and combined weights of the 20 indicators (b). Source: authors' calculations.

3.2 Dynamics of the integral index

Table 5 and Figure 3 present the SDI for 2020–2025. All enterprises improved their strategic position, but at very different speeds and from very different baselines. E4 increased its SDI from 0.561 to 0.854 and in 2025 entered the "high" zone; E2 rose from 0.580 to 0.804; E1 almost doubled its index, from 0.430 to 0.764, with the highest momentum among the leading group (12.2% per year). E3 recorded the highest momentum overall (16.3% per year) but started from the lowest baseline (0.276) and reached only 0.587, the "moderate" zone. E5 grew by only 7.7% per year and remained in the "low" zone (0.512).

The 2022 cost shock is clearly visible as a flattening of all curves and as a dip of K^{traj} below 1 for E1 (0.991), E3 (0.944) and E5 (0.870). The leaders recovered in 2023, whereas E3 and especially E5 did not return to their planned paths. By 2025 the conformity coefficients range from 0.765 (E5) to 1.104 (E4). The implied time to full attainment τ is 1.9 years for E4, 2.3 for E1, 3.3 for E2 and 3.5 for E3, all within the remaining five-year horizon, but 9.1 years for E5, meaning that at its current pace E5 would reach its 2030 targets only around 2034.

Table 5. Integral Strategic Development Index, planned index and dynamic characteristics, 2020–2025

Ent.	2020	2021	2022	2023	2024	2025	Plan 2025	K^{traj} 2025	μ, % p.a.	Level 2025
E1	0.430	0.496	0.541	0.638	0.704	0.764	0.709	1.078	12.2	Sustainable
E2	0.580	0.637	0.666	0.728	0.760	0.804	0.787	1.022	6.7	Sustainable
E3	0.276	0.364	0.405	0.473	0.531	0.587	0.631	0.929	16.3	Moderate

Ent.	2020	2021	2022	2023	2024	2025	Plan 2025	K^{traj} 2025	μ, % p.a.	Level 2025
E4	0.561	0.611	0.670	0.737	0.777	0.854	0.773	1.104	8.7	High
E5	0.354	0.404	0.423	0.456	0.481	0.512	0.670	0.765	7.7	Low

Note: μ is the compound annual growth rate of the SDI for 2020–2025; the level is assigned according to Table 3. Source: authors' calculations.

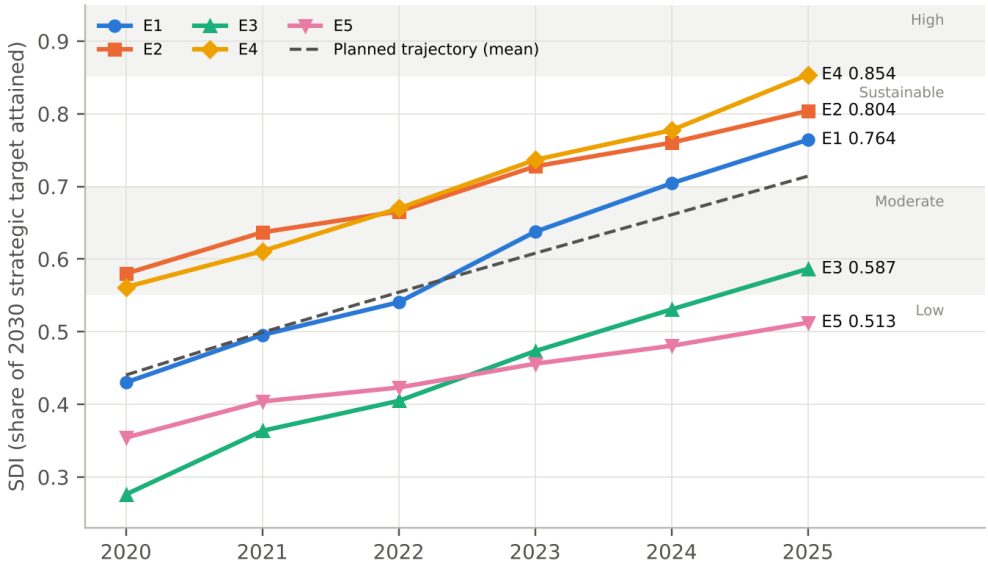


Figure 3. Dynamics of the integral SDI of enterprises E1–E5 against the average planned trajectory, 2020–2025; shaded bands show the classification zones. Source: authors' calculations.

3.3 Structure of strategic development by dimension

Sub-indices reveal the sources of the integral results (Table 6, Figures 4 and 5). E4 is the most balanced enterprise: all five sub-indices lie between 0.763 and 0.934, and its innovation-investment sub-index is the highest in the panel (0.934). E2 combines excellent production performance (G_P = 0.942) and finance with comparatively weak market and ESG dimensions. E1 is strong in finance and production but lags in ESG (G_E = 0.596), owing to its CO_2 intensity and low substitution rate. E3 demonstrates a typical catch-up profile: its production-technological sub-index (0.771) is close to that of the leaders thanks to modernisation of capacity, but its ESG sub-index is the lowest in the panel (0.394). E5 is weak across the board, with innovation-investment (0.405) as its most critical dimension.

The effect of the geometric aggregation is visible in the last columns of Table 6. For the most unbalanced enterprises, E3 and E5, the SDI is 2.2 and 2.5 percentage points lower than the arithmetic composite, whereas for the balanced E4 the difference is only 0.7 points. The index therefore rewards balanced execution of the strategy, as intended.

Table 6. Sub-indices of strategic dimensions and integral index, 2025

Ent.	G_F	G_P	G_M	G_I	G_E	SDI (geom.)	Arithmetic	max G / min G
E1	0.830	0.855	0.801	0.758	0.596	0.764	0.772	1.43
E2	0.870	0.942	0.740	0.773	0.732	0.804	0.812	1.29
E3	0.664	0.771	0.711	0.520	0.394	0.587	0.609	1.96
E4	0.810	0.928	0.813	0.934	0.763	0.854	0.861	1.22
E5	0.622	0.674	0.524	0.405	0.458	0.512	0.537	1.66

Note: the last column is an imbalance ratio; a value of 1 indicates perfectly balanced attainment across dimensions. Source: authors' calculations.

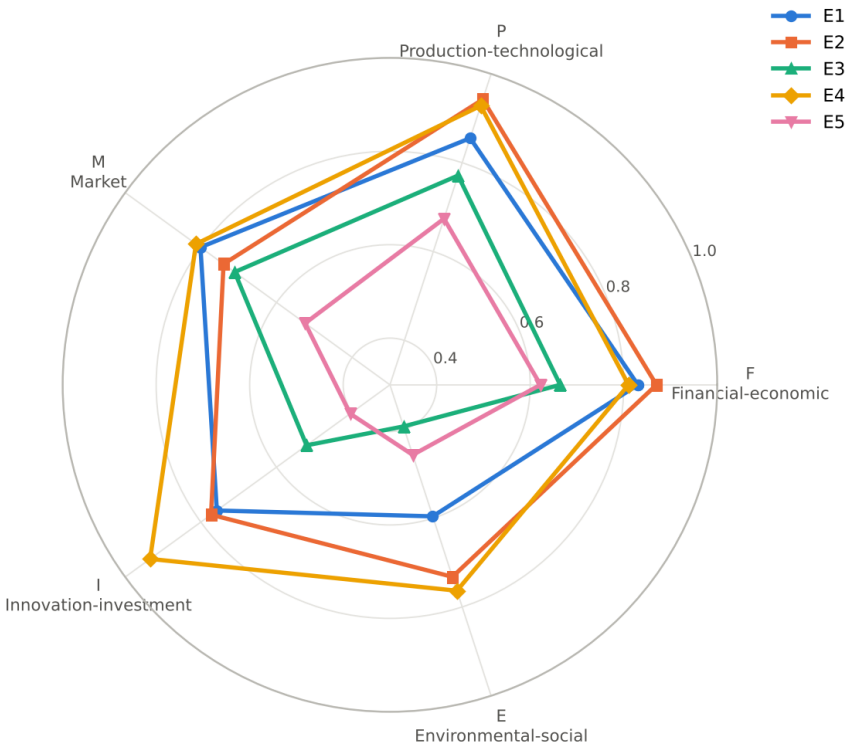


Figure 4. Profile of strategic development by dimension, 2025 (sub-indices G_k). Source: authors' calculations.

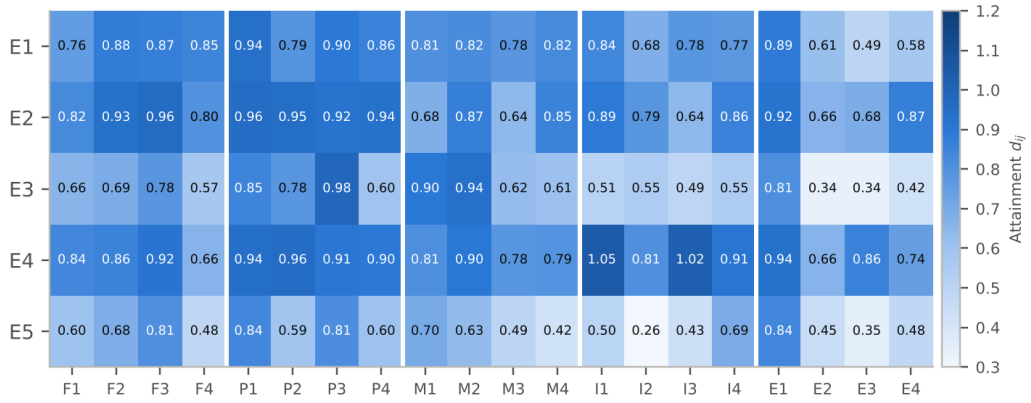


Figure 5. Attainment of 2030 targets by indicator, 2025 (d_{ij}); white lines separate the five strategic dimensions. Source: authors' calculations.

At indicator level (Figure 5), the most frequent deficits concern R&D intensity (I2), the export share (M3), the substitution rate of alternative fuels and SCM (E2) and occupational safety (E3), all of which are below 50% of target in at least one enterprise. These are exactly the goals with the highest entropy weights, which confirms that the index concentrates attention on the strategic goals where execution differs most between enterprises. The only cases of over-fulfilment ($d > 1$) are E4's investment intensity and share of new products, which remain below the cap.

3.4 Strategic positioning

Combining the level of the SDI with trajectory conformity yields the strategic positioning matrix (Figure 6). E4, E2 and E1 are "strategic leaders": their SDI exceeds 0.70 and they are ahead of schedule. E1 crossed from the catch-up to the leader quadrant in 2024. E3 and E5 are located in the "strategic risk zone" (SDI < 0.70, $K^{traj} < 1$), but their situations differ: E3 is only 7.1% behind plan and has high momentum, so targeted correction of its market and ESG programmes may suffice, whereas E5 is 23.5% behind

plan with a widening gap, which signals that either its action plan or its targets require revision.

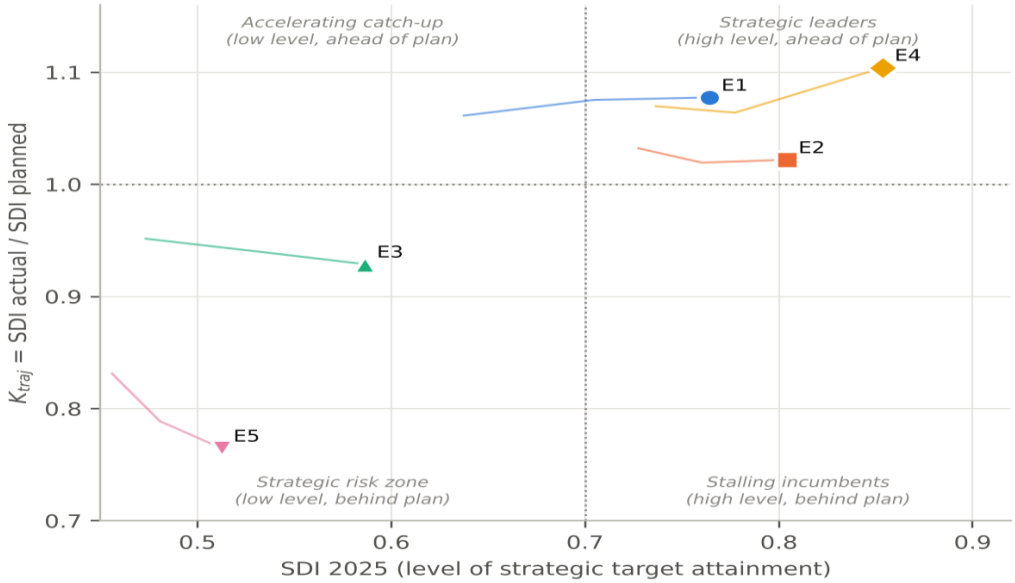


Figure 6. Strategic positioning matrix: SDI level versus trajectory conformity K^{traj}, 2025; thin lines show the movement of each enterprise over 2023–2025. Source: authors' calculations.

3.5 Robustness and validity

Cronbach's α for the five dimensions ranges from 0.900 (market) to 0.971 (financial-economic), indicating that the indicators within each dimension measure a coherent construct. Pairwise correlations are, however, high: after removing the common year effect, 24% of indicator pairs still have $|r| > 0.9$, with a maximum of 0.966 between P1 and P4. In the illustrative panel this reflects the small number of enterprises and the strong enterprise-specific execution effect; in real applications, a correlation or variance-inflation check should be used to eliminate redundant indicators before weighting.

The Monte Carlo analysis confirms the stability of the results (Table 7, Figure 7). The mean simulated SDI differs from the baseline by less than 0.007 for every enterprise, and the 90% uncertainty intervals are narrow (width 0.05–0.08). Ranks are virtually invariant: the baseline rank is reproduced in 99.7–100% of runs, and the only rank reversal (E1 and E2 swapping positions 2 and 3) occurs in 0.3% of runs. The median Spearman correlation between baseline and simulated SDI is 1.00. Excluding any single dimension changes the SDI by 1.6–4.2% on average and leaves the ranking unchanged ($\varrho = 1.00$); the largest effect comes from excluding the innovation-investment dimension (4.2%) and the ESG dimension (3.9%). The ranking by SDI coincides with the rankings by the arithmetic composite and by TOPSIS ($\varrho = 1.00$). The TOPSIS scores, however, are relative and stretch the distance between enterprises (from 0.099 to 0.891), whereas the SDI conveys the absolute degree of strategy execution.

Table 7. Robustness of the SDI, 2025

Ent.	SDI	Rank	MC mean	MC 90% interval	Arithmetic	TOPSIS C_i	Freq. of baseline rank
E1	0.764	3	0.766	0.741 – 0.790	0.772	0.659	99.7%
E2	0.804	2	0.806	0.781 – 0.831	0.812	0.692	99.7%
E3	0.587	4	0.593	0.555 – 0.631	0.609	0.304	100.0%
E4	0.854	1	0.855	0.831 – 0.878	0.861	0.891	100.0%
E5	0.512	5	0.519	0.482 – 0.558	0.537	0.099	100.0%

Note: MC – Monte Carlo simulation (10,000 runs with perturbed weights, over-fulfilment cap and aggregation rule). Source: authors' calculations.

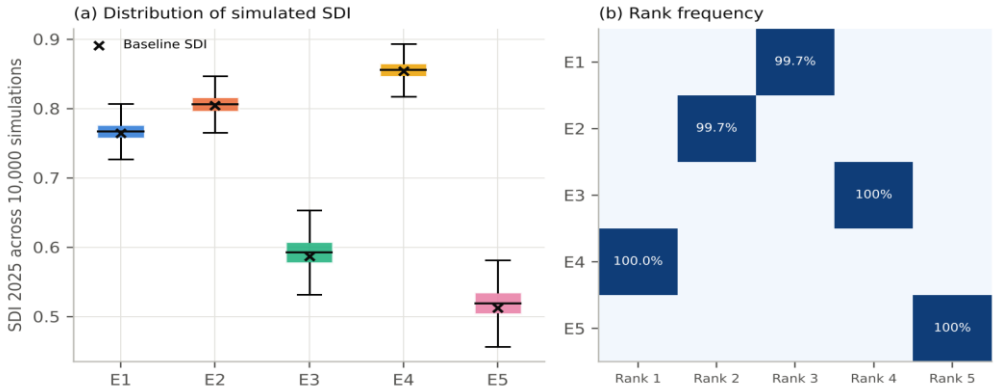


Figure 7. Uncertainty analysis: distribution of simulated SDI in 2025 (a) and frequency of each rank over 10,000 Monte Carlo runs (b). Source: authors' calculations.

4. Discussion

4.1 Interpretation of the findings

The results show that the proposed SDI separates two aspects of strategic performance that conventional evaluation tends to merge: the *level* of target attainment and the *pace* of execution. The case of E3 illustrates why these matters. Judged by momentum alone, E3 is the best performer in the panel; judged by level alone, it is close to the laggard E5. Only the joint use of the SDI and K^{traj} shows that E3 is a fast but unbalanced catch-up enterprise whose strategy is achievable, whereas E5 faces a structural execution problem. Similarly, E1 and E2 have similar SDI levels in 2025, but E1 is gaining on its plan while E2 is merely keeping pace with it, which suggests different managerial agendas: E1 should consolidate its ESG performance, while E2 should consider whether its market targets remain ambitious enough.

The weighting results also have substantive meaning. In building materials manufacturing, production and energy-efficiency goals are relatively standardised across producers, because they depend largely on proven kiln and grinding technologies. Differentiation between enterprises arises mainly from innovation, export orientation and decarbonisation, which is why these goals obtain higher objective weights. This is consistent with industry roadmaps that identify clinker substitution, alternative fuels and new binders as the main levers of future competitiveness.

4.2 Comparison with previous studies

The study builds on the Balanced Scorecard tradition [15], [16] but goes beyond it by providing an explicit aggregation rule and a time-path reference, which answers the call of the performance-measurement literature for dynamic and strategy-linked systems [17], [18]. Compared with AHP–entropy applications to enterprise evaluation [27], [34], the SDI replaces relative normalisation with goal-attainment normalisation, so that the result can be interpreted as a share of the strategy implemented and remains meaningful even for a single enterprise. The choice of geometric aggregation follows the arguments of Ebert and Welsch [30] and Munda and Nardo [31], and the results confirm its practical effect: unbalanced enterprises are penalised by up to 2.5 percentage points. Finally, the robustness protocol corresponds to the recommendations of Saisana et al. [32] and Greco et al. [20]; the very high rank stability suggests that, once targets are fixed, the conclusions drawn from the SDI are not artefacts of particular weighting choices.

4.3 Managerial and policy implications

For enterprise management, the SDI can be embedded in the annual strategic review cycle. The integral index indicates the overall degree of strategy execution; the sub-indices locate the dimensions responsible for deviations; the indicator-level heat map identifies

the specific goals to be corrected; and K^{traj} together with τ serves as an early-warning signal. A practical decision rule follows from the positioning matrix: enterprises in the leader quadrant can raise their targets or extend the horizon; enterprises in the catch-up quadrant should protect the investment programme; stalling incumbents should review execution capacity; and enterprises in the risk zone should revise their action plans or targets.

For public authorities and industry associations, which in Uzbekistan coordinate an extensive programme of capacity expansion, the SDI provides a common language for monitoring enterprise contributions to sectoral goals of the "Uzbekistan – 2030" strategy. Aggregating enterprise SDIs weighted by capacity would give a sectoral strategic index, and the ESG sub-index could inform the allocation of support for decarbonisation projects. Investors and banks could use the index and its trajectory component in the assessment of long-term creditworthiness and project risk.

4.4 Limitations and directions for further research

The study has several limitations. First, the empirical application uses an illustrative, model-generated panel; the methodology must be validated on actual enterprise data, and the numerical results reported here should not be interpreted as an assessment of any real company. Second, the SDI depends on the quality of strategic targets: an enterprise with unambitious targets may obtain a high index. An external benchmark component, for example comparison of targets with best available technology levels, could address this. Third, the linear planned trajectory is a simplification for investment-intensive projects with step-wise effects; milestone-based or S-shaped paths should be used where the strategy provides them. Fourth, the small cross-section limits the reliability of entropy weights and correlation analysis; larger samples would allow principal component analysis and data envelopment analysis as complementary validation tools. Future research may also explore fuzzy AHP to model expert uncertainty, the optimisation of β, and econometric links between the SDI and market value or credit ratings.

5. Conclusion

The paper proposes a methodology for calculating an integral Strategic Development Index to assess the effectiveness of implementing long-term development goals of building materials manufacturing enterprises. The methodology integrates (1) a five-dimensional system of 20 indicators reflecting financial, production, market, innovation and ESG goals; (2) goal-attainment normalisation with bounded over-fulfilment; (3) combined AHP–entropy weighting; (4) weighted geometric aggregation that limits compensation between dimensions; (5) a dynamic block consisting of the trajectory-conformity coefficient, strategic momentum and the time to target; and (6) a classification scale and positioning matrix. The illustrative application shows that the index discriminates clearly between enterprises with different execution profiles, detects deviations from the planned trajectory and identifies the indicators responsible for them. The results are robust to weight uncertainty, aggregation rules and the exclusion of dimensions. The SDI can therefore serve as a practical instrument of strategic control at enterprise level and as a building block for monitoring sectoral development programmes.

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