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CONTACTS

Phone: **+998 50 737 87 88**

Website: <https://ist-journal.uz>

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A METHODOLOGY FOR A MULTIDIMENSIONAL INTEGRAL INDEX OF DEMAND–PRODUCTION ALIGNMENT IN THE BUILDING MATERIALS INDUSTRY

Turdiyev Abdullo Sagdullaevich

Candidate of Economic Sciences, Associate Professor, ALFRAGANUS University

E-mail: a.turdiyev@afu.uz

ORCID: 0009-0008-5259-7220

Abstract. This article develops a formalized methodology for multidimensional assessment of demand–production alignment in the building materials industry. The study specifies the indicators, normalization rules, and aggregation procedure needed to assess quantitative, assortment, spatial-logistics, temporal, and resource-capacity alignment jointly. The methodological design synthesizes established approaches to composite indicators, industrial statistics, forecast evaluation, and missing-data treatment. Five component scores—BQ, BA, BH, BT, and BR—are defined alongside asymmetric normalization of shortages and surpluses, geometric aggregation, a coverage measure (COV), data-quality statuses, and a mandatory constraint triggered by breaches of quality, safety, or environmental requirements. The resulting calculation protocol permits the Integral Matching Index (IMI) to be reported only with its component profile, normalization parameters, uncertainty interval, and data provenance record. A complete industry-level IMI is not calculated because a harmonized panel of orders, inventories, logistics, effective capacity, and resource availability is not currently available. The methodology is intended for subsequent reproducible validation using enterprise data and may be incorporated into sales and operations planning (S&OP) and strategic monitoring. Its practical interpretation focuses on identifying the component that constrains overall alignment rather than merely comparing aggregate scores.

Keywords: Integral Matching Index, demand, production, building materials, alignment, composite indicator, normalization, geometric aggregation, data quality.

INTRODUCTION

Matching aggregate demand and output does not necessarily mean that the building materials market is balanced. A shortage may persist for a particular grade, region, or delivery date even when total output formally matches aggregate requirements. Similarly, nameplate capacity does not guarantee that a production plan is feasible when raw materials, energy, maintenance capacity, or compliance with mandatory quality and safety requirements constrain operations.

The scale of construction activity makes this issue especially relevant. According to preliminary data from the National Statistics Committee of the Republic of Uzbekistan, construction work amounted to UZS 313.8 trillion in 2025, representing growth of 14.2% over 2024 [16]. This monetary measure indicates the overall scale of activity but does not replace physical demand data for specific products. An official presentation on industry development projected building materials output of UZS 53 trillion and exports of USD 1.1 billion for 2025; it also identified unresolved issues relating to quality, standards, logistics, and access to new markets [17]. Because these sectoral figures were presented as projections, this article does not treat them as final observed data or use them to calculate the IMI.

The OECD/JRC handbook requires a composite indicator to rest on a theoretical framework and transparent rules for normalization, weighting, aggregation, and sensitivity analysis [1]. The United Nations recommendations for the Index of Industrial Production emphasize the comparability of classifications, observation units, and time bases [2]. In Uzbekistan, the use of official statistics must also comply with the principles of quality, impartiality, and confidentiality established by the Law on Official Statistics [3].

This study aims to develop a methodology for a multidimensional integral index of demand–production alignment in the building materials industry and to define its components, calculation rules, data requirements, and subsequent empirical validation program. The research question is how heterogeneous dimensions of alignment can be combined without concealing a critical failure in any one dimension or replacing missing data with artificially favorable values. The study contributes a reporting architecture in which an aggregate score

may be reported only when all mandatory data components are available and must be presented together with the component profile, coverage measure, constraints, and reproducibility parameters.

LITERATURE REVIEW

A composite index provides a concise representation of a multidimensional system, but its value depends on the components included, scale direction, target points, weights, and aggregation function [1]. Studies of uncertainty in composite indicators show that weights and aggregation methods can substantially change an object's final score and rank [4–6]. A later review emphasizes that equal weights are convenient as an initial specification but are not neutral and should be tested against alternative schemes [18].

An arithmetic sum allows complete compensation: a high score in one dimension can offset an almost zero score in another. Geometric aggregation penalizes weak components more heavily but requires an explicit rule for zero values and missing observations [1; 4–6]. The proposed methodology therefore combines geometric aggregation with an NA rule and a mandatory constraint: a missing mandatory data component or a breach of quality, safety, or environmental requirements cannot be converted into an average score.

A separate body of literature addresses missing-data treatment and forecast evaluation. Statistical imputation is defensible only under a justified missingness mechanism; mechanical mean substitution can create a fictitious appearance of adequate supply [7; 8]. The temporal component requires scaled errors that are comparable across series and validation on a later period without mixing training and test information [9–11]. Expert weights, including those derived through the analytic hierarchy process (AHP), require disclosure of the expert panel and a consistency assessment of its judgments [12].

The literature provides well-developed general principles for index construction, but the applied case of building materials remains insufficiently formalized when similar aggregate volumes conceal assortment, spatial, temporal, or resource-related failures. The research gap is therefore not the absence of another aggregation formula, but the lack of a unified protocol that simultaneously defines five operational components, distinguishes shortages from surpluses asymmetrically, prevents unjustified compensation, and links the final score to the quality of the underlying evidence.

RESEARCH METHODOLOGY

The study uses a methodological design. It applies construct decomposition, a methodological synthesis of approaches to composite indicators and forecasting, and an analysis of official regulatory and statistical sources [1–3; 9–15]. No primary interviews or surveys were conducted. The unit of observation is defined as product $i \times$ region $r \times$ period t ; when corporate information is available, the unit can be extended to include the enterprise and production-line levels.

Before calculation, the source, cutoff date, forecast vintage as of a specified date, product classification, unit of measurement, period boundaries, transformations, and revision status are recorded. Production, imports, inventories, exports, and demand are converted to a common physical unit and time interval. Nominal value cannot substitute for physical volume without a separate deflation procedure and a comparability assessment. SIAT series, including the official item “Production of Portland Cement,” may provide output context but cannot replace microdata on orders, inventories, and deliveries [13]. Sectoral development measures are considered within the applicable institutional framework [14].

Input-data quality is recorded using statuses A, B, C, and N. Status A denotes direct transactional or official data supported by a verifiable primary record; B denotes aggregated but documented data; C denotes an indirect estimate or proxy with an explicit assumption; and N denotes missing or non-comparable information. The status does not replace the component's numerical value and is reported separately.

ANALYSIS AND RESULTS

The first result is the operationalization of five complementary dimensions of alignment. The notation BQ, BA, BH, BT, and BR is used consistently throughout the article. The English name of the aggregate measure is standardized as the Integral Matching Index (IMI) (Table 1).

Table 1.
Architecture of the IMI Components

Component	Scope	Calculation logic	Minimum data
BQ — quantity	Proximity of available supply to demand	Asymmetric relative gap	Output, imports, opening uncommitted inventory, exports, minimum inventory, demand
BA — assortment	Match between grade, format, and quality structures	One minus total variation distance	Orders and available supply under a common SKU or product-family classification
BH — spatial	Product availability in the target region and delivery window	Weighted geometric combination of BQ and OTIF	Regional demand and deliveries completed in full and on time
BT — time	Forecast accuracy and response speed	MASE and management-response lag	Forecast vintages, plan, actual values, decision date
BR — resources	Plan feasibility subject to capacity and constraints	Geometric coverage of capacity and resources	Effective capacity, raw materials, energy, maintenance, quality, and environmental compliance

Source: Developed by the author based on [1; 2; 7–11].

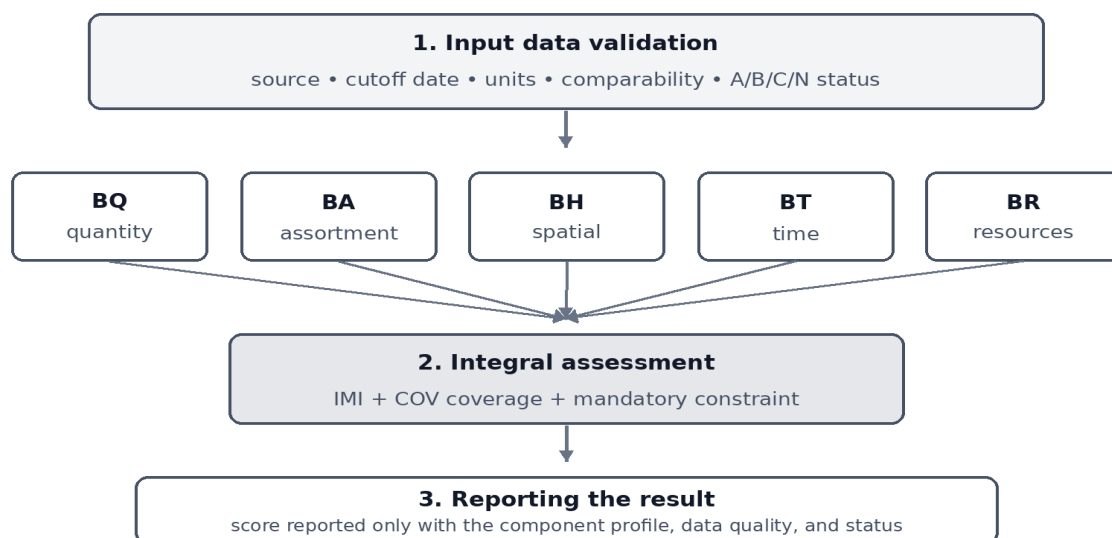


Figure 1. IMI Calculation and Reporting Workflow

Source: Developed by the author.

Formalization of the Components

The quantitative component begins with the resources available to the market. All elements refer to the same product, region, and period: P is output during the period; M is imports actually received during the period; I_{irt}^{beg} is uncommitted inventory at the beginning of the period; X is exports and other pre-existing external commitments; and I_{irt}^{min} is the mandatory safety stock at the end of the period.

$$A_{irt} = P_{irt} + M_{irt} + I_{irt}^{beg} - X_{irt} - I_{irt}^{min}$$

$$g_{irt} = \frac{A_{irt} - D_{irt}}{D_{irt}}, \quad D_{irt} > 0$$

Because the economic losses associated with shortages and surpluses differ, separate half-penalty thresholds ε^- and ε^+ are introduced. Their values are calibrated against historical losses and operating

constraints rather than selected after the result has been observed.

$$\varepsilon(g) = \varepsilon^+ (g \geq 0), \quad \varepsilon^- (g < 0)$$

$$BQ_{irt} = \exp\left[-\ln(2) \frac{|g_{irt}|}{\varepsilon(g_{irt})}\right]$$

When $D = 0$, the relative gap is undefined and BQ is therefore not calculated. The observation is classified in advance as “outside the active market” when $A = 0$ or as “supply with no observed demand” when $A > 0$; the rule for including such cells in subsequent aggregation is fixed before the analysis.

The assortment component compares the demand shares d_k and available-supply shares a_k within a common classification, where k denotes a grade, format, or quality group. If the corresponding total demand or supply is zero, the component is assigned NA.

$$d_k = \frac{D_k}{\sum_k D_k}, \quad a_k = \frac{A_k}{\sum_k A_k}$$

$$BA = 1 - \frac{1}{2} \sum_k |d_k - a_k|$$

The spatial component combines regional quantitative alignment with actual order-fulfillment performance. Here, ω_r is the region's share of aggregate demand, and $OTIF_r$ is the proportion of deliveries completed in full and on time.

$$\omega_r = \frac{D_r}{\sum_r D_r}, \quad BH = \sum_r \omega_r \sqrt{BQ_r \cdot OTIF_r}$$

The temporal component combines forecast accuracy with the lag in management response. MASE is calculated only from forecast vintages produced before the evaluated period; m is the seasonal lag. If the denominator is zero, the time series is too short, or plan-vintage dates have not been retained, BT is assigned NA.

$$MASE = \frac{\text{mean}|D_t - \hat{D}_t|}{\text{mean}|D_t - D_{t-m}|}$$

$$BF = \frac{1}{1 + MASE}, \quad BL = \exp\left[-\ln(2) \frac{L}{L^*}\right], \quad BT = \sqrt{BF \cdot BL}$$

In the formulas, L is the observed lag between a persistent signal and the management decision, while L^* is the acceptable lag specified in advance. This approach prevents forecasts from being evaluated using the data on which they were fitted [9–11].

The resource-capacity component represents the feasibility of the production plan. Q^{eff} is effective capacity after accounting for maintenance and downtime; Q^{plan} is planned output; and R^{avail}_j and R^{need}_j are the available and required quantities of resource j . The weights v_j sum to one and are disclosed in the calculation record.

$$C_0 = \min\left(1, \frac{Q^{\text{eff}}}{Q^{\text{plan}}}\right), \quad C_j = \min\left(1, \frac{R^{\text{avail}}_j}{R^{\text{need}}_j}\right)$$

$$BR = \prod_{j=0}^J C_j^{v_j}, \quad \sum_{j=0}^J v_j = 1$$

A breach of a mandatory quality, safety, or environmental requirement activates a binding constraint. In that case, the management rating is not reported regardless of the numerical value of BR or any other component.

Aggregation, Coverage, and Missing Data

Weighted geometric aggregation is applied to the five component scores $B_j \in [0, 1]$. Equal weights of 0.20 are used only as a transparent initial specification; robustness must be assessed using alternative expert-based, AHP, and statistical weighting schemes [5; 6; 12; 18].

$$IMI = 100 \prod_{j=1}^5 B_j^{w_j}, \quad \sum_{j=1}^5 w_j = 1$$

The clipping operator is defined as $\text{clip}(z, 0, 1) = \min\{1, \max\{0, z\}\}$. It is applied to intermediate scales when values outside $[0, 1]$ are theoretically possible. For two-sided targets, the asymmetric exponential normalization specified for BQ is used. Zeros remain zero and are not replaced with a small positive constant unless a separate sensitivity analysis is conducted.

The reliability of the evidence base is reported separately. For component j , $r_j \in [0, 1]$ is a prespecified measure of coverage and reliability based on source quality, timeliness, granularity, and comparability. The mapping of A/B/C/N statuses to numerical r_j values is disclosed before calculation and tested for sensitivity.

$$COV = \sum_{j=1}^5 w_j r_j$$

If any mandatory component is missing, particularly BT or BR, it is not replaced with the mean of the remaining components. Instead, the IMI is assigned NA and the user receives a partial profile. This rule prevents an information gap from producing a spurious improvement in the index [7; 8] (Table 2).

Validation and Robustness Program

Table 2.
Minimum IMI Validation Program

Test	What varies	Output	Criterion
Content validity	Link between each indicator and component	Indicator–component matrix	Each indicator has one unambiguous purpose
Convergent validity	Association between IMI and operational outcomes	Comparison with OTIF, order backlog, inventories, and price	Direction accords with theory; magnitude and uncertainty are reported
Predictive validity	Subsequent time period	Discrimination between future shortages and surpluses	Only out-of-sample validation results are used
Sensitivity	Weights, aggregation function, ε^- , ε^+ , and boundaries	Range of scores and management statuses	Conclusion is stable under small admissible variations
Robustness to missing data	Missingness mechanism and imputation method	Interval and change in component profile	Dependence on assumptions is disclosed
Uncertainty	Inputs and parameters	Monte Carlo or bootstrap interval for IMI	The interval is reported with the point estimate

Source: Author's synthesis based on [1; 4–11; 18].

Management-zone boundaries are not defined by universal numerical thresholds. They are calibrated using the historical distribution of stable periods, the economic losses caused by shortages and surpluses, and operating limits agreed in advance. After calibration, the thresholds are tested on a later period; they may not be changed after the test result has been observed (Table 3).

Data Readiness for Empirical Validation

Table 3.
Minimum Data Set and Status of the Current Research Base

Data block	Required granularity	Current status	Implication
Orders and lost demand	Product $\times$ region $\times$ month; order date	No harmonized panel	BQ, BA, and regional weights cannot be fully validated
Uncommitted and safety inventories	Opening balance and required closing balance	No comparable series across all products	Available supply A is calculated incompletely

Data block	Required granularity	Current status	Implication
Logistics and OTIF	Order, quantity, promised date, and actual date	No unified transactional database	BH cannot be calculated at industry level
Forecast vintages and decision dates	Forecast issued before the period, actual value, and response date	Insufficient retained vintages	BT is assigned NA
Effective capacity and resources	Downtime, maintenance, raw materials, energy, and constraints	Incomplete coverage	BR is assigned NA
Official industry statistics	Output of selected products and construction activity	Partially available [13; 16; 17]	Used as context but does not replace microdata

Source: Author's assessment of the available research base. The status does not imply that the relevant data are unavailable within individual enterprises.

The result of this article is therefore neither an industry ranking nor an empirically validated time series of the IMI, but a fully formalized protocol for subsequent calculation. A pilot validation requires the selection of one enterprise and one product segment, at least 24–36 consecutive monthly data vintages, and ex ante rules for inclusion, normalization, weighting, and evaluation on a later period.

The proposed architecture differs from the standard sequence of normalization, weighting, and aggregation through three safeguards. First, geometric aggregation limits the extent to which a strong component can compensate for a weak one. Second, the mandatory constraint operates outside the utility function: higher output cannot offset a breach of quality, safety, or environmental requirements. Third, the coverage measure separates the condition of the assessed object from the quality of the supporting evidence.

The approach has practical value within S&OP because the component profile indicates whether managers need to adjust volume, assortment, delivery geography, the forecasting cycle, or the resource plan. The aggregate score should not replace this diagnostic profile. For example, the same IMI can arise from different combinations of BQ and BR, each requiring a different management response.

The methodology has several limitations. The threshold parameters ε^- , ε^+ , and L^* depend on the product segment and associated economic losses; equal weights do not automatically represent the true importance of the components; OTIF is sensitive to the rules used to record the promised date; and corporate data may contain selective missingness. External validity must be assessed separately for cement, glass, ceramics, and other product groups because their logistics, shelf life, and capacity structures differ.

The proposed provisions are consistent with the literature on transparent composite indicators and robustness analysis [1; 4–6; 18], but extend it by introducing an operational rule that withholds the score when mandatory data are incomplete. Testing the economic usefulness of this rule remains a task for the empirical stage and is not presented here as an established result.

CONCLUSION AND RECOMMENDATIONS

This article develops a methodology for a multidimensional integral index of demand–production alignment in the building materials industry. It combines five components: quantity (BQ), assortment (BA), spatial-logistics alignment (BH), time (BT), and resource-capacity adequacy (BR). Shortages and surpluses are normalized asymmetrically, and the components are integrated using a weighted geometric function.

The methodological contribution lies in the joint use of a component profile, the NA rule, the COV coverage measure, and a mandatory constraint. This design prevents missing data or a breach of a critical requirement from being concealed by a high value in another component. The methodology is formalized as a protocol for subsequent reproducible validation rather than presented as an already validated industry index.

For practical implementation, enterprises should establish a source register and a unified product classification; retain forecast vintages and promised delivery dates; calculate the IMI first in a pilot segment; calibrate thresholds against economic losses; and report the score only with all five components, COV, A/B/C/N statuses, normalization parameters, and an uncertainty interval. After pilot validation, the methodology may be incorporated into the enterprise's S&OP and strategic monitoring systems.

This article does not create a new open microdataset or claim to provide a complete industry-level

calculation of the IMI. Official sources are used to describe the context and are accessible through the links in the reference list. Reproducing the full index requires harmonized corporate data on orders, inventories, logistics, forecast vintages, effective capacity, and resources. The formulas, variable definitions, NA rules, coverage measure, and validation program are provided to support such a calculation; access to commercially sensitive data must be governed by the data owner and applicable confidentiality requirements.

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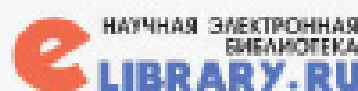
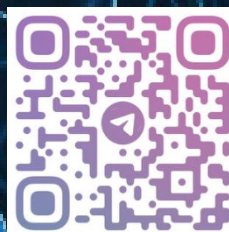
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