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EVALUATING READY MIXED CONCRETE SUPPLIER SELECTION: AN INTEGRATED ANALYTIC HIERARCHY PROCESS (AHP) AND TOPSIS MULTI-CRITERIA DECISION-MAKING FRAMEWORK

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ABSTRACT

Ready Mixed Concrete (RMC) has transformed modern civil engineering practices by offering enhanced quality controls, accelerated construction velocity, and reduced environmental footprint over traditional on-site manual mixing. However, selecting the most appropriate RMC supplier is a highly complex problem characterized by multiple qualitative and quantitative criteria that are often in conflict. This paper presents a structured multi-criteria decision-making (MCDM) framework that integrates the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to systematize RMC supplier selection. The framework was empirically tested through a survey conducted in four major industrial cities in Gujarat, India (Ahmedabad, Nadiad, Anand, and Vadodara), capturing 60 validated responses from RMC plant managers (21), contractors (26), and consultants (13). The AHP analysis was used to derive global weights for 10 main criteria and 38 sub-criteria, with inconsistent responses corrected using standard consistency improvement techniques. Spearman's rank correlation was applied to evaluate regional consensus, showing high levels of agreement (e.g., r_s = 0.855 between Anand and Vadodara). TOPSIS was subsequently utilized to rank concrete supply alternatives, establishing Respondent 3 (R3) as the ideal selection and Respondent 25 (R25) as the least preferred. This research article demonstrates that combining AHP and TOPSIS minimizes subjective cognitive biases, protects projects against material supply risks, and provides a rigorous decision tool for construction developers and project managers.

KEYWORDS: Ready Mixed Concrete, Analytic Hierarchy Process (AHP), TOPSIS, Spearman Correlation, Multi-Criteria Decision-Making (MCDM), Supplier Evaluation

The construction and infrastructure development sectors serve as primary drivers of economic growth globally, particularly within emerging economies like India. With the increasing size and technical complexity of modern civil infrastructure projects, there is a progressive shift from conventional labor-intensive on-site concrete mixing methods to industrial-scale Ready Mixed Concrete (RMC) utility. Conventionally, concrete was mixed on construction sites under highly variable environmental conditions, exposing materials to inconsistent proportioning, erratic curing, and labor-dependent errors. RMC, mixed in highly computerized, automated batching plants and transported to construction sites via specialized transit mixers, offers a reliable solution to these technical limitations, securing excellent quality control and accelerating overall construction timelines.

The operational benefits of RMC are extensive. They include higher concrete durability due to precise water-cement ratio controls, reduction of materials storage on congested urban construction sites, electronic recording of batch weight data, and a substantial decrease in local noise and air pollution from loose aggregate and dust storage on-site. However, despite these clear advantages, implementing an RMC utility strategy introduces critical procurement risks. Concrete is a perishable composite material that begins to hydrate and lose workability immediately upon mixing. It must be transported, placed, and compacted within a highly restricted time frame (typically within 2 to 3 hours). Consequently, selecting an RMC supplier is not merely a commercial purchasing transaction but a multi-faceted logistics and quality assurance decision.

In contemporary construction management, selecting a supplier represents a classic multi-criteria decision-making (MCDM) challenge. Project managers must evaluate potential suppliers against dozens of qualitative and quantitative parameters, such as direct unit costs, transportation lead times, plant capacity, safety records, and quality certifications. Many of these criteria are in direct conflict; for instance, a supplier offering the lowest direct unit cost may be situated at a substantial distance from the site, thereby introducing delivery setting risks and high indirect transportation overheads. To resolve these conflicts, a scientific, mathematically robust supplier evaluation model is required to replace subjective heuristics and prevent catastrophic project delays or material quality failures.

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This study aims to develop and validate an integrated decision-making framework utilizing two popular MCDM methods: the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The AHP method decomposes the complex RMC supplier evaluation problem into a structured hierarchy of main criteria and sub-criteria, using pairwise comparison matrices to calculate objective priority weights. TOPSIS is then applied to rank competing concrete suppliers by measuring their Euclidean distance to an 'ideal' mathematical solution and a 'negative-ideal' solution. The model is empirically validated through a rich survey dataset of 60 completed questionnaires from RMC plant managers, consultants, and contractors across four rapidly growing cities in Gujarat, India (Ahmedabad, Nadiad, Anand, and Vadodara). Additionally, Spearman's rank correlation is used to test regional consensus across these markets.

LITERATURE REVIEW

Multi-criteria supplier evaluation and decision-making techniques have received considerable attention in operations research and industrial engineering over the past two decades. In the construction industry specifically, research shows that relying solely on direct procurement costs for material selection leads to poor quality outcomes, schedule overruns, and adversarial contractor relationships. Consequently, researchers have progressively explored structured algorithms to systematize material selection.

Thomas L. Saaty (2008) pioneered the Analytic Hierarchy Process, demonstrating its utility as an organized mechanism to structure complex decisions, collect relevant subjective judgments, and convert qualitative expert opinions into consistent quantitative priorities. The flexibility of AHP has led to its wide application in various engineering settings, ranging from the energetic rehabilitation of historical structures (Gigliarelli *et al.*, 2011) to complex vendor selection in highly specialized telecommunication systems (Tam and Tummala, 2001). Within civil engineering, Daxini, Bhatt, and Pitroda (2013) demonstrated that AHP represents a highly effective framework to resolve shortcomings in standard subjective supplier selection practices. They advocated that encouraging stakeholders to utilize AHP directly enhances overall project success.

RMC operations are highly mechanical and capital-intensive, requiring advanced scheduling and logistics modeling. Al-Araidah *et al.* (2012) developed a comprehensive Activity-Based Costing (ABC) model for RMC delivery, dividing total cost into on-floor, delivery, waste, and penalties. Their model highlighted that distance, traffic conditions, and transit fleet maintenance directly dictate final RMC unit costs. This accentuates why physical distance and transportation logistics represent high-priority criteria during evaluation. Similarly, supply chain research by Shahroodi *et al.* (2012) and Politis, Klumpp, and Celebi (2010) emphasized that supplier selection represents a critical strategic decision where managers must balance world-class quality, real-time delivery logistics, financial stability, and operational risk mitigation.

While AHP excels at determining the relative weights of decision criteria, ranking a large number of alternatives through pairwise comparisons can lead to severe cognitive fatigue and inconsistency. To address this limitation, researchers often pair AHP with the TOPSIS method. TOPSIS, initially formulated by Hwang and Yoon, operates on the principle that the selected alternative should have the shortest geometric distance to the positive ideal solution and the longest distance to the negative ideal solution. This method has been successfully deployed to prioritize construction process safety solutions on-site (Liaudanskiene *et al.*, 2009), rank design project managers based on technical skillsets (Vainiunas *et al.*, 2010), and resolve multi-criteria supplier selection challenges under tight operational constraints (Sennaroglu and Şen, 2012; Jadidi *et al.*, 2010). Building on these prior works, this study uses a unified, empirically grounded approach to apply AHP and TOPSIS to the unique regional context of the RMC market in Gujarat, India.

METHODOLOGICAL FRAMEWORK

The proposed RMC utility selection model utilizes a sequential three-phase methodology: (1) AHP-based weight calculation for selection criteria, including consistency check and correction, (2) Spearman rank correlation to assess consensus between stakeholder groups across the targeted cities, and (3) TOPSIS-based multi-criteria evaluation to rank competing concrete supply options.

Analytic Hierarchy Process (AHP)

The AHP process structures the decision problem hierarchically, descending from the primary goal to main criteria, sub-criteria, and finally, alternatives. Decision-makers conduct pairwise comparisons at each level of the hierarchy using Saaty's standard 1-to-9 scale, where 1 indicates equal importance, 3 indicates moderate importance of one factor over another, 5 indicates strong importance, 7 indicates demonstrated dominance, and 9 indicates absolute dominance. The comparison results are compiled into a square reciprocal matrix A of size n x n, where a_ij represents the relative importance of criterion i over criterion j, and $a_{ji} = 1/a_{ij}$.

The priorities (weights) are determined by computing the principal eigenvector w associated with the maximum eigenvalue lambda_max, such that A * w = λ_{max} * w. Because human judgment is inherently inconsistent, a consistency check must be conducted. The Consistency Index (CI) is computed as follows:

$$CI = (\lambda_{max} - n) / (n - 1)$$

The Consistency Ratio (CR) is then calculated by dividing the CI by a Random Index (RI) derived from a large sample of randomly generated matrices of the same size. If the CR is less than 0.10 (10%), the pairwise comparison matrix is accepted as sufficiently consistent. If the CR exceeds 10%, the comparisons are deemed inconsistent and must be revised. In this study, inconsistent responses were mathematically corrected using the consistency improvement technique proposed by Lamata and Pelaez (2002), which systematically adjusts highly inconsistent entries while preserving the decision-maker's original preference direction.

Spearman Rank Correlation Coefficient

To check if the preferences of stakeholders from different city environments are in agreement, Spearman's rank correlation coefficient (r_s) is calculated. This non-parametric measure determines the strength of the relationship between two ranked datasets (e.g., criteria rankings from Nadiad vs Vadodara). It is calculated using the formula:

$$r_s = 1 - [6 * \Sigma(D_{i2}) / (N^3 - N)]$$

where D_i represents the difference between the ranks assigned to criterion i by two separate groups, and N is the total number of criteria evaluated (N = 38 sub-criteria). A coefficient value close to +1.00 indicates perfect agreement, while a value close to 0 indicates a lack of correlation, signifying high market variance.

TOPSIS Method

TOPSIS evaluates Competing Supply Alternatives against the criteria weights determined by AHP. The TOPSIS protocol consists of the following steps:

1. Construct the normalized decision matrix, converting diverse units into dimensionless values using vector normalization.

2. Build the weighted normalized decision matrix by multiplying each column of the normalized matrix by its associated AHP weight.

3. Determine the positive ideal solution (A*) and negative ideal solution (A-) representing the best and worst possible outcomes across all criteria.

4. Compute the Euclidean separation measures (S_i* and S_{i-}) for each alternative from the ideal and negative-ideal solutions.

5. Calculate the relative closeness coefficient (C_i*) to the ideal solution, where $C_i^* = S_i - / (S_i^* + S_{i-})$. An alternative with C_i^* close to 1.00 represents the optimal selection.

EMPIRICAL CASE STUDY AND DATA COLLECTION

To validate the utility of the integrated AHP-TOPSIS model, an extensive questionnaire-based survey was conducted. The survey targeted three primary groups of stakeholders: RMC plant managers (who understand concrete batching and logistics capacities), contractors (who utilize RMC and manage on-site pouring schedules), and consultants (who serve as quality inspectors and specify concrete design requirements). The geographic scope of the study comprised four major industrial and urban development hubs in the state of Gujarat, India: Ahmedabad (the largest metropolitan hub), Vadodara (a key industrial center), Anand (a rapidly developing district), and Nadiad (a prominent urban center).

A total of 100 questionnaire forms were distributed to pre-screened construction professionals across the four cities. Following a rigorous follow-up campaign, 60 highly detailed, valid questionnaires were retrieved and analyzed. This 60% response rate is exceptionally strong for MCDM modeling, where qualitative and logical consistency is prioritized over raw respondent volume. The demographic and city-wise distribution of these 60 validated responses is presented in Table 1.

The survey instrument structured the RMC selection criteria hierarchically. Through comprehensive consultations with expert engineers and academic literature, 10 primary (main) criteria categories were established: Quality Control, Cost, Delivery, Quantity, Manpower, Safety Measures, Financial Capability, Commercial Capability, Laboratory, and Managerial Capability. To secure granularity, each main category was further decomposed into specific sub-criteria, resulting in a comprehensive 38-sub-criteria framework. For example, Quality Control was evaluated using two sub-criteria: Quality of Material (raw ingredient specification and hydration control) and Standard & Certification (ISO and bis certifications). Cost was divided into Direct Cost (concrete price per cubic meter) and Indirect Cost (wash, pumping, and admix additives). Delivery logistics were assessed using four critical parameters: Location (proximity to construction site), Size of Transit mixers, Delivery Lead Time, and Time Consuming (traffic delays and site discharge time).

Table 1: Respondent Demographic and City-wise Distribution (Collected N = 60)

Targeted City	RMC Plant Managers	Contractors	Consultants	Total Respondents
Ahmedabad	3	7	5	15
Nadiad	2	9	4	15
Anand	7	6	2	15
Vadodara	9	4	2	15
Total Stakeholders	**21**	**26**	**13**	**60**

DATA ANALYSIS AND EMPIRICAL RESULTS

The collected dataset was processed sequentially using Microsoft Excel and customized MATLAB scripts. The first step was to check consistency and calculate individual and group criterion weights using AHP. Next, Spearman rank correlation was calculated to determine regional consensus across city markets. Finally, the generated weights were input into the TOPSIS algorithm to rank competing RMC alternatives.

AHP Pairwise Comparisons and Criteria Weights

Pairwise comparisons were executed at all levels of the hierarchical model. To illustrate, Table 2 presents the reciprocal-normalized comparison matrix and the resulting local weights generated for the Delivery sub-criteria group by a representative respondent. The column sum is normalized to 1.000, and the row average yields the local weight (LW) of each criterion.

Table 2: Pairwise Comparison Normalized Matrix for Delivery Sub-Criteria

Delivery Sub-Criteria	Location (LC)	Size of Transit Mixer (STM)	Delivery Lead Time (DLT)	Time Consuming (TC)
Location (LC)	0.167	0.286	0.100	0.200
Size of Transit Mixer (STM)	0.167	0.286	0.300	0.400
Delivery Lead Time (DLT)	0.500	0.286	0.300	0.200
Time Consuming (TC)	0.167	0.143	0.300	0.200

By taking the average of the normalized rows in Table 2, the local weights for the Delivery criteria were calculated as: Location LW_LC = 0.188, Size of Transit Mixer LW_STM = 0.288, Delivery Lead Time LW_DLT = 0.321, and Time Consuming LW_TC = 0.202. This indicates that among delivery logistics, Delivery Lead Time (32.1%) carries the highest local priority, closely followed by Transit Mixer Size (28.8%).

A similar pairwise comparison was executed for the Managerial sub-criteria (Organizational Structure [OS], Types of Decision maker [TOD], Direction of Work [DOW], Maintenance [MT], and Customer Feedback [CF]). The matrix normalization yielded the following local weights:

• Organizational Structure (OS) LW_OS = 0.393

• Types of Decision Maker (TOD) LW_TOD = 0.168

• Direction of Work (DOW) LW_DOW = 0.156

• Maintenance (MT) LW_MT = 0.094

• Customer Feedback (CF) LW_CF = 0.188

To obtain global weights (GW) across the entire hierarchy, each sub-criterion's local weight was multiplied by its parent main-criterion weight. Following consistency correction, the final global priorities of the 38 sub-criteria were summarized. The top 10 most critical global criteria across the entire survey pool of 60 respondents were determined as follows:

1. Large Quantity (GW = 0.0827 - 0.0830) [Rank 1]

2. Quality of Material (GW = 0.101 - 0.107) [Rank 2]

3. Delivery Lead Time (GW = 0.0379 - 0.0415) [Rank 3]

4. Sales/Utilization Area (GW = 0.0385 - 0.0524) [Rank 4]

5. Manager (GW = 0.0286 - 0.0338) [Rank 5]

6. Location (GW = 0.0292 - 0.0321) [Rank 6]

7. Equipment Safety (GW = 0.0292 - 0.0322) [Rank 7]

8. Standard and Certification (GW = 0.0167 - 0.0270) [Rank 8]

9. Accidents (GW = 0.0270 - 0.0309) [Rank 9]

10. Managerial Capability Sub-Factors [Rank 10]

Geographic Consensus (Spearman Rank Correlation)

To establish whether the generated weights represent a homogenous regional market structure, Spearman's rank correlation coefficient (r_s) was calculated between the various city respondent groups. The rankings derived from comparisons of 38 criteria were tabulated side by side. As a representative case, Table 3 details the correlation coefficient calculation between the Anand and Vadodara respondent groups, measuring rank differences (D_i) and squared differences (D_{i2}).

Table 3: Representative Spearman Correlation Calculation: Anand vs Vadodara (N = 38 sub-criteria)

Representative Criteria	Parent Main Criteria	Anand Rank	Vadodara Rank	Difference (Di)	Squared Diff (Di^2)
Quality of Material	**Quality Control**	3	3	0	0
Standard & Certification	**Quality Control**	19	10	9	81
Direct Cost	**Cost**	35	35	0	0
Indirect Cost	**Cost**	1	1	0	0
Location	**Delivery**	14	17	-3	9
Size of Transit Mixer	**Delivery**	7	7	0	0
Delivery Lead Time	**Delivery**	4	4	0	0
Time Consuming	**Delivery**	9	14	-5	25
Large Quantity	**Quantity**	2	2	0	0
Equipment Safety	**Safety Measures**	6	9	-3	9
Spearman Coefficient	**r_s = 1 - [(6 * Σ(D_{i2})) / (N^3 - N)]**	**Total Σ(D_{i2}) =**	**1124**	**r_s =**	**0.855**

By summing the squared differences across all 38 criteria, the total Σ(D_{i2}) was found to be 1124. Applying the Spearman rank correlation formula with N = 38 yields:

$r_s = 1 - [(6 * 1124) / (38^3 - 38)] = 1 - [6744 / 54834] = 1 - 0.123 = 0.855$

The calculated Spearman correlation coefficient (r_s = 0.855) indicates a very strong positive correlation between the criteria rankings of construction experts in Anand and Vadodara. A similar analysis conducted across other city pairings (e.g., Ahmedabad - Nadiad, Ahmedabad - Anand, and Nadiad - Vadodara) consistently yielded correlation values close to +1.00. This proves that construction stakeholders in Gujarat share a cohesive consensus on RMC procurement priorities, reconciling geographic market variances.

TOPSIS Supplier Evaluation and Ranking

To rank alternatives, the weighted normalized decision matrix was constructed using the criteria weights derived from AHP. Euclidean distances to the ideal solution (A*) and negative-ideal solution (A-) were calculated for each respondent alternative across the 38 sub-criteria. Representative results showing separation measures for the first ten respondents (R1 through R10) for some commercial, lab, and managerial sub-criteria (such as banking history, sales policy, test facility, testing procedures) are detailed in Table 4.

Table 4: TOPSIS Separation and Closeness Coefficients for Competing Alternatives (R1-R10)

RMC Alternative	Separation from Ideal (S_i*)	Separation from Negative Ideal (S_i-)	Closeness Coefficient (C_i*)	Rank Outcome
Respondent R1	0.00948	0.00105	0.0997	49
Respondent R2	0.00841	0.00140	0.1427	41
Respondent R3 (Best)	**0.00685**	**0.00171**	**0.1997**	**1 (Optimal)**
Respondent R4	0.00961	0.00427	0.3076	12
Respondent R5	0.00203	0.00915	0.8184	19
Respondent R6	0.00162	0.00731	0.8185	26
Respondent R7	0.00235	0.01056	0.8180	13
Respondent R8	0.00129	0.00900	0.8746	4
Respondent R9	0.00183	0.00823	0.8181	15
Respondent R10	0.00092	0.00826	0.8998	3

The overall ranking calculated across all 60 respondent alternatives revealed that Respondent 3 (R3) achieved the optimal selection index (Rank 1, closeness index near to ideal), protected by robust performance across the high-weight criteria: Quality of Material, Large Quantity, and Delivery Lead Time. In contrast, Respondent 25 (R25) achieved the lowest ranking (Rank 60) due to poor quality compliance and remote batching location, maximizing its proximity to the negative ideal solution.

DISCUSSION AND PRACTICAL IMPLICATIONS

The empirical findings of this integrated AHP-TOPSIS model carry deep practical implications for the construction engineering and procurement industry in developing urban regions. Standard purchasing practices frequently over-emphasize Direct Cost as the dominant criteria. However, our model demonstrates that 'Large Quantity' and 'Quality of Material' consistently command higher global weights among practitioners. This finding matches the industrial realities of modern concrete construction. ready-mixed concrete is typically deployed in high-volume structural operations, such as casting multi-story foundation rafts or massive slab components. A single material quality failure in a structural pour can necessitate extensive retrofitting or demolitions, costing hundreds of times the initial purchase savings.

Furthermore, our analysis identifies Delivery Lead Time and Location as key operational priorities. Because concrete is a highly perishable composite material, transportation delay represents a risk of material hydration, leading to slump loss and premature setting. Suppliers that are structurally remote from the site or lack a sufficient transit fleet size expose projects to extreme quality and structural durability risks. The integrated model systematically captures these multi-dimensional logistics risks, ensuring that distance and time delays are penalized within the TOPSIS ranking process. By evaluating competing concrete alternatives through this framework, developers can move away from subjective selection, ensuring that their supply chain is secure and aligned with technical standards.

CONCLUSIONS & RECOMMENDATION

This paper presented a scientific multi-criteria decision-making framework integrating AHP and TOPSIS to systematize Ready Mixed Concrete (RMC) supplier selection. The AHP model successfully decomposed the multi-dimensional decision problem into a standard hierarchy, weighting 10 main criteria and 38 sub-criteria using pairwise comparison matrices verified through consistency check checks. The empirical validation across Gujarat's four prominent urban hubs (Ahmedabad, Nadiad, Anand, and Vadodara) captured 60 completed responses, revealing a strong regional consensus, as proven by Spearman rank correlation coefficients consistently approaching +1.00 (and r_s = 0.855 between Anand and Vadodara). Finally, the TOPSIS algorithm successfully evaluated competing supply alternatives, establishing Respondent 3 as the optimal choice based on its high compliance with quality standards and logistical proximity, while Respondent 25 was identified as the worst option.

For construction companies and developers, implementing this MCDM model secures a rigorous, audit-ready tool that eliminates cognitive biases and protects concrete structural integrity. Future research avenues may explore the integration of fuzzy logic (Fuzzy-AHP and Fuzzy-TOPSIS) to model cognitive uncertainty and linguistic ambiguity under extremely volatile market environments, or expand the model's application to specialized heavy infrastructure projects, including high-performance marine and highway concrete works.

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