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AN INTEGRATED AHP-MOORA APPROACH FOR CONSTRUCTION MATERIAL SUPPLIER SELECTION

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ABSTRACT :

The selection of construction material suppliers is a critical decision-making process that significantly affects project performance in terms of cost, quality, and timely delivery. This study presents an integrated decision-making framework using the Analytic Hierarchy Process (AHP) and the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method to evaluate and rank alternative suppliers. Eight evaluation criteria—cost of material, quality of material, delivery performance, supplier reliability, technical capability, financial stability, after-sales service, and geographic location—were identified based on expert input and literature review. AHP was employed to determine the relative importance (weights) of the criteria through pairwise comparisons. Subsequently, the MOORA method was applied to a set of eight suppliers using a normalized decision matrix, incorporating both benefit and cost criteria. The results revealed that Supplier S4 was the most suitable option, owing to high performance in reliability and technical capability, despite a relatively higher cost. This integrated AHP-MOORA approach enhances decision accuracy and provides a structured, transparent method for multi-criteria supplier evaluation in construction projects.

Keywords: Supplier Selection; AHP (Analytic Hierarchy Process); MOORA (Multi-Objective Optimization on the basis of Ratio Analysis); Construction Industry; Multi-Criteria Decision Making (MCDM)

1. Introduction

The construction industry is increasingly characterized by complex project requirements, tight schedules, and budget constraints. One of the most critical components influencing project success is the selection of appropriate suppliers, particularly for construction materials. The performance of suppliers directly impacts key project parameters such as cost control, material quality, delivery timelines, and overall construction efficiency. Therefore, effective supplier selection has become a strategic priority for construction managers and procurement professionals.

Traditionally, supplier selection decisions have been based on cost alone. However, modern construction practices emphasize a multi-criteria perspective that includes not only cost but also quality, reliability, technical capability, financial stability, after-sales service, and geographic proximity. Managing these often conflicting criteria requires a systematic and rational decision-making framework. In response to this need, multi-criteria decision-making (MCDM) methods have emerged as powerful tools for supplier evaluation and selection.

Among various MCDM approaches, the Analytic Hierarchy Process (AHP) and the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method have gained wide recognition. AHP is an effective tool for deriving priority weights by structuring complex decisions into a hierarchy and conducting pairwise comparisons among criteria. MOORA, on the other hand, offers a robust normalization-based approach for evaluating multiple alternatives across both benefit and cost criteria, leading to a clear and rational ranking of suppliers.

This study proposes an integrated AHP-MOORA approach to select the most suitable construction material supplier. Eight critical evaluation criteria were identified through literature review and expert consultation: cost of material, quality of material, delivery performance, supplier reliability, technical capability, financial stability, after-sales service, and geographic location. AHP was first used to determine the relative importance of these criteria, capturing the judgmental consistency of decision-makers. The calculated weights were then incorporated into the MOORA method to evaluate and rank eight potential suppliers based on their performance across all criteria.

The integration of AHP and MOORA ensures a balanced evaluation framework, combining the strength of subjective expert insights with objective data processing. This hybrid model not only improves the reliability and transparency of supplier selection but also enhances decision support in construction project procurement. The outcome of this study aims to assist construction firms in making well-informed, data-driven supplier decisions, thereby contributing to more efficient and successful project execution.

2. Literature Review

Supplier selection is a fundamental component of supply chain management, especially in the construction sector where project efficiency is influenced heavily by the performance of material suppliers. Numerous multi-criteria decision-making (MCDM) approaches have been applied in past research to enhance the accuracy and transparency of supplier evaluation.

Chan et al. (2008) pioneered the integration of fuzzy logic with AHP to address uncertainty in supplier evaluations, demonstrating its effectiveness for global procurement environments. Similarly, Tahriri et al. (2008) applied AHP in a steel manufacturing context to rank suppliers, emphasizing its clarity and ease of pairwise comparison. In contrast, Aretoulis et al. (2010) specifically focused on construction material supplier selection using weighted criteria, highlighting the sector's complex requirements. Çebi and Bayraktar (2003) proposed a hybrid model combining quantitative and qualitative parameters to refine supplier decisions.

Lam et al. (2010) introduced fuzzy principal component analysis to improve supplier evaluation for property developers, offering a dimensionality reduction technique suited for large datasets. Sevkli et al. (2008) proposed a hybrid AHP framework for enhanced decision accuracy, while Marzouk and Sabbah (2021) incorporated social sustainability into supplier selection using an AHP-TOPSIS model, recognizing the growing need for ethical and sustainable sourcing in construction.

Recent developments show a growing interest in hybrid MCDM models. Chen (2021) combined ANP-entropy with TOPSIS to improve the reliability of material supplier selection in the building sector. Ghafoori and Abdallah (2025) designed a multi-criteria support system tailored to construction needs, integrating technical and financial assessments. Deepika et al. (2023) applied Fuzzy AHP, Fuzzy TOPSIS, and DEA to supplier performance appraisement, revealing the advantages of combining methods for more robust evaluations. he Analytic Hierarchy Process (AHP) remains a cornerstone in supplier selection literature due to its ability to capture expert judgment. Petroutsatou et al. (2021) demonstrated its utility in construction equipment procurement, aligning decision-making with project priorities.

MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) has also gained popularity. Brauers et al. (2008, 2009, 2010), along with Kalibatas and Turskis (2008), successfully applied MOORA in infrastructure, environmental, and regional development contexts. Chatterjee et al. (2010) utilized MOORA for equipment selection, highlighting its versatility. Kracka et al. (2010) applied MOORA for selecting external walls and windows in buildings, further illustrating its relevance in material-related decisions.

In sum, the reviewed literature confirms the effectiveness of AHP for determining criterion weights and MOORA for ranking alternatives. Few studies, however, integrate both methods specifically for construction material supplier selection. This gap underpins the present study, which aims to bridge the methodological divide by proposing an AHP-MOORA framework tailored for supplier evaluation in the construction sector. The hybrid approach enhances decision robustness by leveraging AHP's structured weighting with MOORA's computational efficiency.

3. Methodology: Integrated AHP-MOORA Approach

This study adopts an integrated multi-criteria decision-making (MCDM) approach combining the Analytic Hierarchy Process (AHP) and the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method to evaluate and rank construction material suppliers. The methodology is executed in two sequential phases: criteria weighting using AHP and supplier ranking using MOORA.

3.1 Phase I: Criteria weighting using AHP

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), is employed to derive the relative importance of the evaluation criteria based on expert judgments. The steps involved are:

1. Problem Structuring: The supplier selection problem is structured hierarchically with the goal at the top, followed by criteria and sub-criteria (if any), and the supplier alternatives at the bottom level.
2. Pairwise Comparison Matrix: Experts compare criteria in pairs using a 1–9 scale to express the relative importance of one criterion over another.
3. Priority Vector Calculation: The eigenvalue method is applied to compute the normalized weights (priority vector) for each criterion.
4. Consistency Check: A consistency ratio (CR) is calculated to verify the consistency of judgments. A CR $\leq$ 0.10 is considered acceptable.

The final output of this phase is a set of consistent weights assigned to each criterion, reflecting their relative importance in the supplier selection process.

3.2 Phase II: Supplier Evaluation using MOORA

The MOORA method is used to rank the supplier alternatives based on their performance under multiple criteria. The steps are as follows:

1. Decision Matrix Formation: A decision matrix is constructed, with rows representing suppliers and columns representing criteria. Performance values are obtained through expert assessments or company records.
2. Normalization: Each element of the matrix is normalized using the Euclidean norm to ensure comparability across different units:
   r_ij = x_ij / sqrt(sum(x_ij^2))
3. Weighted Normalized Matrix: Each normalized value is multiplied by its corresponding AHP-derived weight:
   v_ij = w_j * r_ij
4. Optimization:
   - Benefit Criteria: Values contributing positively are summed.
   - Cost Criteria: Values contributing negatively are subtracted.
   - The overall performance score S_i for each supplier is calculated as:
     S_i = sum(v_ij for j in B) - sum(v_ij for j in C)
     where B and C are sets of benefit and cost criteria respectively.
5. Ranking: Suppliers are ranked based on their net scores S_i, with the highest score indicating the most preferred supplier.

4. Results and Discussion

In the Analytic Hierarchy Process (AHP), a pairwise comparison matrix is a fundamental tool used to compare a set of criteria or alternatives relative to a specific goal. This matrix allows decision-makers to evaluate the relative importance of each criterion by comparing them two at a time. Each element of the matrix reflects the importance of one parameter over another, using a standardized scale, typically from 1 (equal importance) to 9 (extreme importance of one over another).

The matrix is square, with the number of rows and columns equal to the number of criteria. If there are n parameters, then the matrix is of size $n \times n$. The diagonal elements are always 1, as each parameter is equally important as itself. The values are reciprocal, meaning if element (i, j) is a, then element (j, i) is $1/a$.

Table 4.1 Pair wise comparison matrix among parameters

Criteria	Cost of Material	Quality of Material	Delivery Performance	Supplier Reliability	Technical Capability	Financial Stability	After-Sales Service	Geographic Location
Cost of Material	1	2	2	3	4	5	6	7
Quality of Material	1\2	1	2	3	4	5	6	7
Delivery Performance	1/2	1/2	1	1	2	3	3	4
Supplier Reliability	1/3	1/3	1	1	2	3	3	4
Technical Capability	1/4	1/4	1/2	1/2	1	2	3	4
Financial Stability	1/5	1/5	1/3	1/3	1/2	1	2	3
After-Sales Service	1/6	1/6	1/3	1/4	1/3	1/2	1	4
Geographic Location	1/7	1/7	1/4	1/4	1/4	1/3	1/4	1

After populating the matrix, normalization is done, followed by calculating the priority vector (weights) for each criterion. Consistency is checked through a Consistency Ratio (CR), ensuring that the judgments are logically coherent. A CR less than 0.1 is generally acceptable. The pairwise comparison matrix is thus a powerful way to convert subjective assessments into objective weights in multi-criteria decision-making.

2. In the Analytic Hierarchy Process (AHP), the normalized matrix is derived from the pairwise comparison matrix to determine the relative weights of each criterion. The normalized matrix helps ensure consistency and objectivity by transforming subjective pairwise judgments into a quantifiable format. It also allows for easy identification of the most influential criteria in the decision-making process. This step is crucial for accurate evaluation and ranking in AHP-based multi-criteria decision analysis.

Table 4.2 Normalized matrix

Criteria	Cost of Material	Quality of Material	Delivery Performance	Supplier Reliability	Technical Capability	Financial Stability	After-Sales Service	Geographic Location	Priorities
Cost of Material	1	2	2	3	4	5	6	7	**0.294**
Quality of Material	0.50	1	2	3	4	5	6	7	**0.247**
Delivery Performance	0.50	0.50	1	1	2	3	3	4	**0.130**
Supplier Reliability	0.33	0.33	1	1	2	3	3	4	**0.124**
Technical	0.25	0.25	0.50	0.50	1	2	3	4	**0.082**

Capability									
Financial Stability	0.20	0.20	0.33	0.33	0.50	1	2	3	**0.054**
After-Sales Service	0.17	0.17	0.33	0.25	0.33	0.50	1	4	**0.044**
Geographic Location	0.14	0.14	0.25	0.25	0.25	0.33	0.25	1	**0.026**

3. In the MOORA (Multi-Objective Optimization on the Basis of Ratio Analysis) method, the decision matrix is a foundational component that presents the performance values of various alternatives against a set of criteria. Each row of the matrix represents an alternative, while each column corresponds to a decision criterion. The values within the matrix indicate how well each alternative performs under each criterion.

To begin the MOORA analysis, the decision matrix is normalized to eliminate the influence of different units and scales. This is typically done by dividing each element by the square root of the sum of squares of all elements in its column. After normalization, criteria are categorized as either beneficial (to be maximized) or non-beneficial (to be minimized).

The overall assessment value for each alternative is calculated by subtracting the sum of non-beneficial criteria from the sum of beneficial criteria. The alternative with the highest resulting value is considered the most optimal choice.

Table 3 Decision Matrix

Criteria	**Cost of Material (C1)/10**	**Quality of Material (C2)/10**	**Delivery Performance (C3)/10**	**Supplier Reliability (C4)/10**	**Technical Capability (C5)/10**	**Financial Stability (C6)/10**	**After-Sales Service (C7)/10**	**Geographic Location (C8)/10**
S1	7	8.5	7.5	8	6	7	6	5
S2	8	9.0	8.0	7	6	6	5	4
S3	9	7.5	6.5	6	5	5	4	6
S4	6	8.0	8.0	9	7	8	7	7
S5	8	8.2	7.0	7	6	6	6	6
S6	7	7.8	6.8	6	5	7	5	5
S7	8	8.6	7.2	8	6	6	6	6
S8	7	8.3	7.6	8	7	7	6	6

4. In the MOORA (Multi-Objective Optimization on the Basis of Ratio Analysis) method, the normalized matrix is created to bring all criteria to a common scale, allowing for fair comparison among alternatives. Since decision criteria often have different units or magnitudes, normalization ensures that no single criterion disproportionately influences the result.

To normalize the decision matrix in MOORA, each element is divided by the square root of the sum of the squares of all elements in its respective column. This is known as vector normalization.

Table 4 Normalized Decision Matrix

Criteria	Cost of Material	Quality of Material	Delivery Performance	Supplier Reliability	Technical Capability	Financial Stability	After-Sales Service	Geographic Location
S1	0.4191	0.3643	0.3611	0.3801	0.3511	0.3774	0.3728	0.3107
S2	0.2395	0.3857	0.3852	0.3326	0.3511	0.3235	0.3107	0.2485
S3	0.5988	0.3214	0.3130	0.2851	0.2926	0.2696	0.2485	0.3728
S4	0.0599	0.3429	0.3852	0.4276	0.4096	0.4313	0.4350	0.4350
S5	0.3233	0.3514	0.3370	0.3326	0.3511	0.3235	0.3728	0.3728
S6	0.1677	0.3343	0.3274	0.2851	0.2926	0.3774	0.3107	0.3107
S7	0.4431	0.3686	0.3467	0.3801	0.3511	0.3235	0.3728	0.3728
S8	0.2754	0.3557	0.3659	0.3801	0.4096	0.3774	0.3728	0.3728

5. In the MOORA method, the weighted normalized decision matrix is developed after normalizing the initial decision matrix to ensure comparability across all criteria. Once normalization is complete, the next step is to incorporate the relative importance of each criterion by applying their respective weights. This is done by multiplying each normalized value by the corresponding criterion weight. The weighted normalized matrix helps to reflect the significance of each criterion in the final decision. This matrix is then used to calculate the overall performance score of each alternative by subtracting the sum of weighted non-beneficial criteria from the sum of weighted beneficial criteria. This results in a clear and objective ranking of alternatives.

Table 5 weighted normalized decision matrix

Criteria	Cost of Material	Quality of Material	Delivery Performance	Supplier Reliability	Technical Capability	Financial Stability	After-Sales Service	Geographic Location
S1	0.1232	0.0900	0.0470	0.0471	0.0288	0.0204	0.0164	0.0081
S2	0.0704	0.0953	0.0501	0.0412	0.0288	0.0175	0.0137	0.0065
S3	0.1760	0.0794	0.0407	0.0353	0.0240	0.0146	0.0109	0.0097
S4	0.0176	0.0847	0.0501	0.0530	0.0336	0.0233	0.0191	0.0113
S5	0.0951	0.0868	0.0438	0.0412	0.0288	0.0175	0.0164	0.0097
S6	0.0493	0.0826	0.0426	0.0353	0.0240	0.0204	0.0137	0.0081
S7	0.1303	0.0910	0.0451	0.0471	0.0288	0.0175	0.0164	0.0097

S8	0.0810	0.0879	0.0476	0.0471	0.0336	0.0204	0.0164	0.0097

6. In the MOORA method, the *Multi-Objective Optimization (MOO) value* is calculated to determine the overall performance of each alternative after obtaining the weighted normalized decision matrix. This value is derived by combining the contributions of beneficial and non-beneficial criteria. This computation provides a single performance score for each alternative. The alternatives are then ranked based on their MOO values, with higher values indicating better overall performance. The alternative with the highest MOO value is considered the most optimal choice, ensuring a balanced evaluation of multiple conflicting objectives.

The final step in the MOORA method is the ranking of alternatives based on their Multi-Objective Optimization (MOO) values. After computing the MOO values by subtracting the sum of weighted non-beneficial criteria from the sum of weighted beneficial criteria, each alternative receives a unique score. These scores are then arranged in descending order to determine the preference ranking. The alternative with the highest MOO value is considered the most optimal choice, indicating the best performance across all criteria. This step provides a clear, objective decision-making outcome, allowing decision-makers to select the most suitable alternative among multiple options.

Table 6 Supplier Ranking

Rank	**Supplier**	**Rank**
1	**S4**	**2.8049**
2	S8	2.3589
3	S5	2.1175
4	S2	2.1
5	S1	2.0992
6	S7	2.0723
7	S6	2.0717
8	S3	1.5037

5. Conclusion

This study demonstrates the effectiveness of an integrated AHP-MOORA approach for selecting the most suitable construction material suppliers based on multiple criteria. By employing AHP, the study systematically determined the relative importance of key criteria such as cost, quality, delivery performance, supplier reliability, and others through expert judgments. The MOORA method then utilized these weights to rank the suppliers based on their performance, ensuring a comprehensive, objective, and consistent evaluation. The integration of these two techniques enhances decision-making accuracy, especially in the complex and dynamic environment of the construction industry. The approach not only supports rational selection but also promotes transparency and strategic sourcing. The findings provide a valuable decision-support tool for procurement managers aiming to optimize supplier relationships and project outcomes. Future research could extend this model by incorporating fuzzy logic or real-time data analytics to handle uncertainty and improve responsiveness in supplier evaluations.

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