Application of Triangular FuzzyTOPSIS Method for Cement Supplier Selection for a Construction Firm in India

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Abstract

The rapid growth in the Indian construction industry has led to a need for efficient supply chain management and timely procurement of raw materials, particularly cement. Choosing suppliers is crucial to project completion, so a robust and reliable process is essential. The study proposed an application of the Triangular Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to address conflicts and uncertainties in supplier selection. In this study, Multi-Criteria Decision Making (MCDM) is employed to evaluate and rank potential cement suppliers on various criteria such as quality, delivery time, reliability, after-sales support, reputation, experience, etc. for Design Hub, Mumbai. The results consistently ranked ACC, Birla Corporation, and India Cement as top suppliers, even when reducing the set of criteria. Hence, this method for selecting suppliers under uncertain conditions was demonstrated as reliable and effective. Construction firms in India would be able to increase supply chain efficiency, reduce costs, and execute projects more efficiently with this approach by combining fuzzy logic with MCDM not only for cement but also for other construction material purchasing. Further exploration of fuzzy MCDM techniques was encouraged by these findings as this method of triangular fuzzy TOPSIS provided a robust and practical solution for choosing cement suppliers, ultimately resulting in improved project outcomes.

Keywords
Multicriteria-Criteria-Decision-Method, Fuzzy TOPSIS, Construction Material, Supplier in India, Cement Supplier

1. Introduction:
In recent decades, India has experienced unprecedented growth in the construction industry due to rapid urbanization and infrastructure development. Construction firms are under mounting pressure to optimize supply chains and ensure timely and reliable raw material procurement. A fundamental component of almost all construction projects, cement ranks highly among these raw materials, making supplier selection one of the most important factors. In recent years, the construction sector has witnessed remarkable expansion in India, contributing significantly to its economy (Bosworth & Collins, 2008). Construction firms face increased pressure to streamline operations and maximize efficiency as demand for quality infrastructure and real estate grows (Bertram et al. 2019). In the cement supply industry, supplier selection is key to successful completion. As part of the process, suppliers are identified that can meet the firm's specific requirements for cost, quality, delivery time, reliability, and after-sales service. An alternative approach to address conflicting criteria and uncertainty is the Triangular Fuzzy TOPSIS method.

MCDM (Multi-Criteria Decision-Making) offers decision-makers a structured process for evaluating and ranking potential alternatives (Chen 2000). The methods have gained popularity across many industries, helping companies handle complex decision-making problems. An MCDM approach to supplier selection is a systematic way to select suppliers based on multiple criteria. When dealing with uncertain and imprecise data, which is a reality in real-life supplier selection, traditional MCDM methods have challenges. Taylan et al. (2014) in their study evaluated risk and selected construction projects effectively using hybrid methodologies including fuzzy AHP and fuzzy TOPSIS. Basahel & Taylan (2016) used a fuzzy AHP technique to identify and evaluate workplace safety conditions on construction sites, as well as a fuzzy TOPSIS model to rank companies by their safety performance, providing valuable insights for benchmarking and inspection priorities. Through integrating quantitative and qualitative criteria, the proposed vendor selection model was demonstrated to enhance reliability by integrating multiple participants and criteria while using fuzzy-TOPSIS by Jang et al. (2017).

Fuzzy logic can solve such challenges. Construction supplier selection involves several interconnected criteria. To address this complexity, the Triangular Fuzzy TOPSIS method incorporates fuzzy sets to represent and handle imprecisions and ambiguities in decision-making. The fuzzy logic method allows decision-makers to express their preferences more realistically because partial membership within a range of values is possible (Chen 2000). Construction firms can improve supply chain efficiency and cost-effectiveness by combining fuzzy logic with TOPSIS (Haq & Boddu, 2017). Traditional binary logic allows only values between 0 and 1, whereas fuzzy logic allows partial memberships within sets between 0 and 1 (Qui et al. 2014). MCDM uses fuzzy logic to deal with uncertainty and vagueness related to supplier selection. Combined with triangular fuzzy numbers, this TOPSIS method enhances the accuracy of imprecise data by incorporating triangular fuzzy numbers into the method.

An important objective of this study is to illustrate how the Triangular Fuzzy TOPSIS method can be used for cement supply in India. We aimed to provide the construction firm with a robust and practical approach to supplier selection using fuzzy logic and MCDM. In addition to improving decision-making, this method is expected to result in better cement supplies, lower costs, and more efficient projects. As a consequence, this research opens up opportunities to explore fuzzy MCDM techniques in other domains and industries. The remainder of this paper is organized as follows. Section 2 presented the triangular fuzzy TOPSIS methodology and calculations for supplier selection in the construction industry. In Section 3, the feasibility of the result was analyzed and provided a comprehensive discussion, as well as concluded the study.

2. Methodology and Analysis:

2.1 Triangular Fuzzy Set

A fuzzy variation of the TOPSIS method that evaluates alternatives based on multiple criteria is the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Junior et al. 2014). In 1981, Hwang and Yoon proposed the classical TOPSIS method. Chen developed the fuzzy TOPSIS method that integrated fuzzy sets into decision-making to deal with uncertainty and imprecision (Nădăban et al. 2016; Chen & Tsao 2008; Chen, 2000). From business economics, transportation, location and resource planning, management, and decision-making to supplier selection, fuzzy TOPSIS is one of the suitable methods (Husain et al. 2021; Sirbiladze et al. 2021; Kahraman et al.2019; Hajiaghaei-Keshteli et al. 2023; Rahman & Shohan 2016).

In this study perception of the management of the firm was considered. However, based on personal experience the perception could vary from person to person. The rating assignment was done on qualitative parameters, hence inputting the number set into the rating terminology would not eliminate the ambiguity or vagueness of the interviewees' preferences. In such cases fuzzy set, where a membership function rather than assigning numerical values to the linguistics terms. Membership functions defined the relationship between the qualitative parameters (x) and the degree of membership (μ_x), which could be between zero to one. In this study, the numerical values of verbal expressions used were shown in Table 1.

To convert these numerical values into fuzzy sets the illustration in Figure 1 was followed.

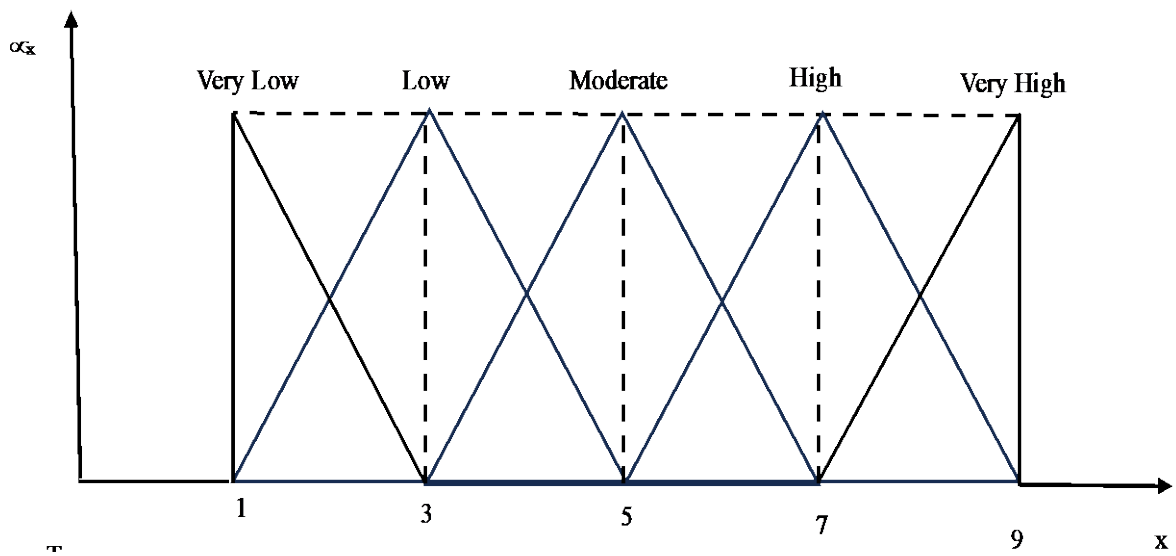

Figure 1. Triangular fuzzy set illustration

Table 1. Numerical values and fuzzy sets of verbal expressions

Importance	Very Low	Low	Moderate	High	Very High
Rate	1	3	5	7	9
Fuzzy Set	1,1,3	1,3,5	3,5,7	5,7,9	7,9,9

2.2 Data Collection
The data was collected from the procurement manager, civil engineer, and project manager of Design Hub, Borivali East, Mumbai, independently. Design Hub's cement suppliers: Ambuja, Ultratech, ACC, JSW, Birla Corp, Kerakoll, and India Cement. The eight criterion they consider for selecting suppliers are Cost, Quality, Delivery Time, Reliability, After-Sales Support, Environmental Compliance, Reputation and Experience, and Capacity and Scalability.

2.3 Calculation and Result
The fuzzy TOPSIS method followed the following methodology (figure 2).

lculate Closeness Coefficient and Rank

Figure 2: Fuzzy TOPSIS Methodology

The combined decision matrix (table 2) was calculated using the following equation:

$$a_{ij} = \min\{a_{ij}^k\}, b_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ij}^k, c_{ij} = \max\{c_{ij}^k\}$$

Where, k= number of decision maker, i = row number and j= column number
Then the normalized fuzzy decision matrix (table 3) was calculated using fuzzy weights (w) from the following equation:

$$w_{j1} = \min\{w_{j1}^k\}, w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{j2}^k, w_{j3} = \max\{w_{j3}^k\}$$

Where, k= number of decision maker, j = criterion number

$$\text{for benefit criterion: } r_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right), \text{ where, } c_j^+ = max_i\{c_{ij}\}$$

$$\text{for non} - \text{benefit criterion: } r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}},\right), \text{ where, } a_j^- = min_k\{a_{ij}\}$$

Using the fuzzy weights and normalized fuzzy decision matrix, the weighted normalized fuzzy decision matrix was calculated (table 4). The next step was to determine the fuzzy positive ideal solution, FPIS (A^+) and fuzzy negative ideal solution, FNIS (A^-). Using A^+ and A^- the distance from FPIS and FNIS was determined as shown in Tables 5 and 6, respectively.

Table 2. Combined decision matrix

Criteria	Cost			Quality			Delivery Time			Reliability			After-Sales Support			Environmental Compliance			Reputation and Experience			Capacity and Scalability		
Ambuja	5	7	9	7	9	9	7	9	9	7	9	9	3	5.3	7	1	3	5	7	9	9	7	9	9
Ultratech	5	7	9	7	9.7	9	7	9	9	7	9	9	3	5.3	7	1	3.7	5	7	9	9	7	9	9
ACC	5	7	9	5	7	9	5	7	9	3	5	7	1	1	3	1	3	5	5	7	9	5	7	9
JSW	5	7.3	9	7	9.3	9	7	9	9	7	9.7	9	3	5	7	1	3	5	7	9.7	9	5	7.7	9
Birla Corp	5	7	9	5	7	9	5	7	9	3	5	7	1	1	3	1	3	5	5	7	9	5	7	9
Kerakoll	5	7	9	7	9	9	7	9	9	7	9	9	3	5	7	1	3	5	7	9	9	7	9.7	9
India Cement	5	7	9	5	7	9	5	7	9	3	5	7	1	1	3	1	3.3	5	5	7	9	5	7.3	9

Table 3: Normalized fuzzy decision matrix

Criteria	Cost			Quality			Delivery Time			Reliability			After-Sales Support			Environmental Compliance			Reputation and Experience			Capacity and Scalability		
Ambuja	0.6	0.7	1	0.8	1	1	0.8	1	1	0.8	1	1	0.4	0.8	1	0.2	0.6	1	0.8	1	1	0.8	1	1
Ultratech	0.6	0.7	1	0.8	1.1	1	0.8	1	1	0.8	1	1	0.4	0.8	1	0.2	0.7	1	0.8	1	1	0.8	1	1
ACC	0.6	0.7	1	0.6	0.8	1	0.6	0.8	1	0.3	0.6	0.8	0.1	0.1	0.4	0.2	0.6	1	0.6	0.8	1	0.6	0.8	1
JSW	0.6	0.7	1	0.8	1	1	0.8	1	1	0.8	1.1	1	0.4	0.7	1	0.2	0.6	1	0.8	1.1	1	0.6	0.9	1
Birla Corp	0.6	0.7	1	0.6	0.8	1	0.6	0.8	1	0.3	0.6	0.8	0.1	0.1	0.4	0.2	0.6	1	0.6	0.8	1	0.6	0.8	1
Kerakoll	0.6	0.7	1	0.8	1	1	0.8	1	1	0.8	1	1	0.4	0.7	1	0.2	0.6	1	0.8	1	1	0.8	1.1	1
India Cement	0.6	0.7	1	0.6	0.8	1	0.6	0.8	1	0.3	0.6	0.8	0.1	0.1	0.4	0.2	0.7	1	0.6	0.8	1	0.6	0.8	1

Table 4: Weighted normalized fuzzy decision matrix

Criteria	Cost			Quality			Delivery Time			Reliability			After-Sales Support			Environmental Compliance			Reputation and Experience			Capacity and Scalability		
Ambuja	3.9	6.4	9	5.4	9	9	3.9	7	9	3.9	7	9	0.4	0.8	3	0.2	1.8	5	5.4	9	9	5.4	9	9
Ultratech	3.9	6.4	9	5.4	9.7	9	3.9	7	9	3.9	7	9	0.4	0.8	3	0.2	2.2	5	5.4	9	9	5.4	9	9
ACC	3.9	6.4	9	3.9	7	9	2.8	5.4	9	1.7	3.9	7	0.1	0.1	1.3	0.2	1.8	5	3.9	7	9	3.9	7	9
JSW	3.9	6.1	9	5.4	9.3	9	3.9	7	9	3.9	7.5	9	0.4	0.7	3	0.2	1.8	5	5.4	9.7	9	3.9	7.7	9
Birla Corp	3.9	6.4	9	3.9	7	9	2.8	5.4	9	1.7	3.9	7	0.1	0.1	1.3	0.2	1.8	5	3.9	7	9	3.9	7	9
Kerakoll	3.9	6.4	9	5.4	9	9	3.9	7	9	3.9	7	9	0.4	0.7	3	0.2	1.8	5	5.4	9	9	5.4	9.7	9
India Cement	3.9	6.4	9	3.9	7	9	2.8	5.4	9	1.7	3.9	7	0.1	0.1	1.3	0.2	2.0	5	3.9	7	9	3.9	7.3	9

Table 5: Distance from fuzzy positive ideal solution (FPIS)

Criteria	Cost	Quality	Delivery Time	Reliability	After-Sales Support	Environmental Compliance	Reputation and Experience	Capacity and Scalability
Ambuja	0.00	0.39	0.00	0.30	0.00	0.24	0.40	0.39
Ultratech	0.00	0.00	0.00	0.30	0.00	0.00	0.40	0.39
ACC	0.00	1.78	1.10	2.72	1.07	0.24	1.80	1.78
JSW	0.17	0.19	0.00	0.00	0.03	0.24	0.00	1.46
Birla Corp	0.00	1.78	1.10	2.72	1.07	0.24	1.80	1.78
Kerakoll	0.00	0.39	0.00	0.30	0.03	0.24	0.40	0.00
India Cement	0.00	1.78	1.10	2.72	1.07	0.14	1.80	1.62

$$v_{ij} = r_{ij} * w_j$$

$$A^+ = (v_1^+, v_2^+, v_3^+, \dots, v_n^+), where, v_j^+ = max_i\{v_{ij}\}$$

and, $A^- = (v_1^-, v_2^-, v_3^-, \dots, v_n^-), where, v_j^- = min_i\{v_{ij}\}$

$$\text{d} = \sqrt{\frac{1}{3}\left[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2\right]}$$

Then, d_i^+ and d_i^- were calculated from the summation of distances of FPIS and FNIS, respectively.

$$d_i^+ = \sum_{j=1}^{n} d(v_{ij}, v_j^+)$$

$$d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_j^-)$$

The final step was to compute the closeness coefficient (CC_i). The rank of the supplier was given based on the CC_i values in ascending order (table 7).

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}$$

3. Discussion and Conclusion:

Construction companies faced many challenges when selecting cement suppliers, which led to the use of the Triangular Fuzzy TOPSIS method. ACC, Birla Corporation, and India Cement consistently ranked highest, whether a reduced set of four criteria or the full set of eight criteria was evaluated. This study demonstrated that the findings are robust even with narrowed-down criteria (figure 3), showing a match rate of 85.71% between the two approaches. A study had demonstrated the reliability of Triangular Fuzzy TOPSIS for selecting cement suppliers (Büyüközkan & Güleryüz, 2016). The method allowed well-informed decision-making by handling uncertainties and inaccurate data inherent in supply chain evaluation. In order to achieve a smooth supply of cement for construction projects, Design Hub should consistently select ACC, Birla Corp, and India Cement as top suppliers. By identifying strengths and weaknesses, decision-makers could make informed choices, contributing to overall project efficiency.

With uncertain data, the Triangular Fuzzy TOPSIS proved more effective. In dynamic and uncertain business environments, fuzzy logic yielded more accurate results when partial memberships in sets were considered (Khashei et al., 2009). Therefore, not only cement but also other materials supplier selection should be practiced by utilizing fuzzy TOPSIS method. Although, as the method used personal preference for rating the criterion, the result could vary for different interview selections or in case of various circumstances, fuzzy TOPSIS would be the most reliable method for supplier selection under uncertainty.

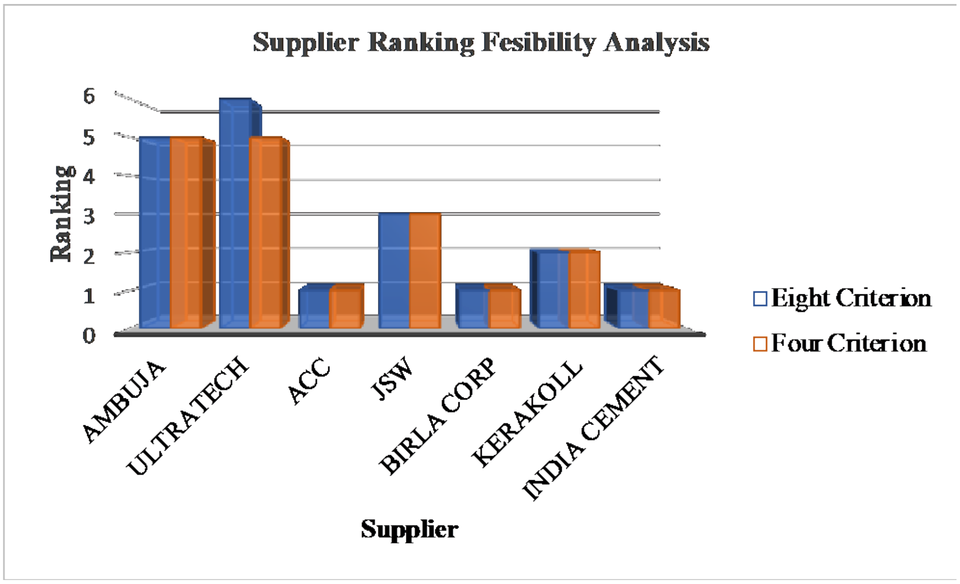

Figure 3. Supplier ranking with fuzzy TOPSIS method

Table 6: Distance from fuzzy negative ideal solution, FNIS

Criteria	Cost	Quality	Delivery Time	Reliability	After-Sales Support	Environmental Compliance	Reputation and Experience	Capacity and Scalability
Ambuja	0.17	1.46	1.10	2.49	1.07	0.00	1.46	1.46
Ultratech	0.17	1.78	1.10	2.49	1.07	0.24	1.46	1.46
ACC	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JSW	0.00	1.62	1.10	2.72	1.06	0.00	1.80	0.39
Birla Corp	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kerakoll	0.17	1.46	1.10	2.49	1.06	0.00	1.46	1.78
India Cement	0.17	0.00	0.00	0.00	0.00	0.10	0.00	0.19

Table 7: Supplier ranking

Criteria	di+	di-	CC	Rank
Ambuja	1.7	9.2	0.8	5
Ultratech	1.1	9.8	0.9	6
ACC	10	0.2	0	1
JSW	2.1	8.7	0.8	3
Birla Corp	10	0.2	0	1
Kerakoll	1.3	9.5	0.9	2
India Cement	10	0.5	0	1

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