CHAPTER 122

Selection of Construction Contractors using Fuzzy Analytical Hierarchy Process (FAHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS)

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ABSTRACT

The success of construction projects hinges on selecting the right contractor, but traditional methods often struggle due to the subjective nature and complexity of evaluating contractors. This study proposes an integrated approach combining the Fuzzy Analytical Hierarchy Process (AHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to improve contractor selection. Fuzzy AHP addresses subjectivity in expert opinions by assigning relative weights to key contractor selection criteria, such as project quality, experience, safety records, cost estimation accuracy, and adherence to timelines. (Tafazzoli, 1861). These weighted criteria are subsequently applied in the Fuzzy TOPSIS algorithm, which ranks contractors by evaluating their performance relative to an ideal (optimal) and a negative (least desirable) solution. The most suitable contractor is determined by minimizing their distance from the ideal solution while maximizing their distance from the negative solution. (Y *et al.*, 2024) The result is a more accurate and reliable contractor selection process that can enhance project outcomes. By using Fuzzy AHP and Fuzzy TOPSIS, the study demonstrates how this approach streamlines contractor selection, ultimately contributing to the overall success of construction projects. (Wang, 2023).

Keywords: Fuzzy analytical hierarchy process (Fuzzy AHP); Fuzzy technique for order preference by similarity to ideal solution (Fuzzy TOPSIS); Contractor selection; Subjectivity.

1.0 Introduction

1.1 What do you mean by MCDM?

Contractor selection is most important in the construction business. Traditional contractor selection methods are usually faced with the problem of ambiguity and subjectivity. The MCDM provides a model-based process for selection that increases the probability of success. This is done based on various criteria like cost, quality, experience, safety, and financial stability.

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1.2 Problems in construction contractor selection

Traditional contractor selection methods are usually faced with the problem of ambiguity and subjectivity. The MCDM provides model-based structured selection processes that increase the likelihood of a better selection decision. (Sahoo, 2023)

- Subjectivity in Assessment
- Multiple Criteria Complexity
- Inconsistent Weighting of Criteria
- External Factors Affecting Performance
- Risk of Poor Outcomes

1.3 Role of MCDM in construction contractor selection

MCDM techniques help address contractor selection challenges by:

- Establishing evaluation criteria
- Defining weights for each criterion
- Gathering and analyzing data
- Ranking contractors based on an objective methodology

Common criteria in contractor selection include:

- *Technical Competence:* Experience, past project success, and workforce expertise.
- *Financial Stability:* Cash flow, credit rating, and financial reserves.
- *Project Management Ability:* Planning, risk management, and adherence to deadlines.
- *Safety Records:* Compliance with safety standards and historical performance.
- *Quality Assurance:* Past work quality and customer satisfaction.

2.0 Literature Review

2.1 Problems in construction contract selection

This research compilation underscores the necessity of robust contractor selection, moving beyond the traditional lowest-bid approach. Multi-criteria decision-making (MCDM) methods like AHP, ANP, and TOPSIS are advocated, emphasizing key factors such as safety, financial stability, technical expertise, and past performance. (Aghajan, 2025) The studies highlight the importance of integrating both quantitative and qualitative data, recognizing contextual differences between public and private sectors, and regional variations. Tailored selection frameworks, accounting for specific project requirements and stakeholder preferences, are crucial. (Yang, 2014) Furthermore, the research emphasizes understanding causal relationships between selection criteria and project outcomes. This necessitates comprehensive pre-qualification standards and refined decision-making processes to mitigate risks and ensure project success. (Amireh, 2022)

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2.2 Criteria for selecting construction contractors

Here the various options of the choice of the contractor are considered, as the reference being made to the fact that the basic criterion was only the cost, and currently, the evaluation is extensive, including many indicators (Jaskowski, 2010). The key factors defining the quality of the contractor are safety, sustainability, financial resources, professionalism of work, and management abilities. Such methodologies as AHP, TOPSIS, and Sustainability are growing in importance with research focusing on green building practices and CO2 emissions. Trust, past performance, and quality control are also important. Research examines main contractor and subcontractor selection, revealing regional differences and industry-specific priorities. (Y *et al.*, 2024) The studies argue in favor of structured evaluation frameworks which integrate stakeholder input and quantifiable metrics, to enhance project success rate and lower the risk and the uncertainty. Also, they criticize the preference for the lowest-bidder approach and emphasize the necessity for data-driven, comprehensive selection processes.

2.3 Multi-criteria decision-making (MCDM) methods for contractor selection

This research synthesizes findings from numerous studies, emphasizing the evolution of contractor selection methodologies. Traditional approaches, often reliant on lowest-bid awards, are increasingly challenged by multi-criteria decision-making (MCDM) methods like AHP, ANP, TOPSIS, and PROMETHEE. Key studies such (A., M.Z.X., & C., 2022) on green building criteria, (A.R., A.M., S.H., N.I.A.B., & N.A., 2021)on safety, and (Tafazzoli, 1861) on subcontractor selection, alongside others, highlight the shift towards comprehensive evaluations encompassing safety, financial stability, technical expertise, and past performance. These works collectively advocate for tailored frameworks and data-driven processes, recognizing contextual variations and the importance of understanding causal relationships for project success.

2.4 Application of fuzzy analytical process in contractor selection

This section examines diverse contractor selection methodologies, including Fuzzy AHP, VIKOR, and ANP, addressing multi-criteria decision-making (MCDM) complexities. Studies like the 2020 Operational Research in Engineering Sciences publication, (X *et al.*, 2024)ANP study and research introducing BWM and SIR methods are highlighted. These approaches, incorporating fuzzy logic and quantified SWOT analysis, aim to mitigate subjectivity and enhance project outcomes by considering factors beyond bid prices, such as financial strength and technical expertise.

2.5 Application for fuzzy technique for order preference by similarity to ideal solution

This section highlights the shift towards multi-faceted contractor selection, emphasizing non-price factors and utilizing MCDM methods like TOPSIS and Fuzzy AHP. Studies, including Alptekin's work on Turkish public procurement, research on South Kerman Electricity Company's SWOT analysis, and (Izadi, 2013)Fuzzy TOPSIS application

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demonstrates the importance of considering financial stability, risk assessment, and quality control. These papers collectively advocate data-driven decisions that integrate subjective and objective criteria to enhance project success.

3.0 Methodology

The study employs a systematic approach integrating Fuzzy AHP and Fuzzy TOPSIS for contractor selection.

3.1 Questionnaire development

A Fuzzy AHP-TOPSIS questionnaire was developed for contractor evaluation. It collected expert assessments on the importance of criteria and contractor performance. A pilot test on Google Forms was conducted to refine the questionnaire. Ten respondents of diverse backgrounds provided feedback so that the wording was improved, questions that were duplicates were eliminated, and the layout was improved.

3.2 Fuzzy AHP analysis

- Step 1: Define Hierarchical Structure: Clearly define a goal (object of ranking criteria for selection of a contractor) and create a hierarchical model. Identify and group relevant criteria (for example, financial stability, technical excellence, safety) in a structured framework. (Ebrahim Jokar, 2020)
- Step 2: Develop Fuzzy Pairwise Comparison Matrices: Design questionnaires with linguistic scales, like equally important to collecting expert opinions. Transform language terms into triangular fuzzy numbers.

Figure 1: Creating a Fuzzy Pairwise Comparison Matrix

	Sustainable Practices implemented in similar projects	Client Testimonials	Creditworthiness and Rating
Sustainable Practices implemented in similar projects	(1,1,1)	(1,2,3)	(2,3,4)
Client Testimonials	(0.4,0.5,0.6)	(1,1,1)	(0.6,0.667,0.7)
Creditworthiness and Rating	(0.3,0.33,0.4)	(1.4,1.5,1.6)	(1,1,1)

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- Step 3: Fuzzy Synthesis, Consistency Check: Aggregate the fuzzy matrices by the geometric mean or other methods to derive overall fuzzy weights. Calculate the Consistency Ratio (CR) to ensure expert judgments are consistent. De-fuzzify the comparison matrix, compute the consistency index (CI), and compare it to the random consistency index (RI).
- Step 4: Defuzzification: This involves converting fuzzy weights into crisp numbers.
- Step 5: Normalize and Rank: Normalize the De-Fuzzified weights. This makes them sum to one, showing the relative importance of each criterion. Rank the criteria in descending order. Use their normalized weights, with the highest weight indicating the most critical factor. (Osman Taylan, 2014)

Figure 2: Computing the Fuzzy Geometric Weight ri and the Fuzzy Weights wi

Criteria	Fuzzy Geometric mean ri	Fuzzy Weights wi
Sustainable Practices implemented in similar projects	**(6.096,7.177,6.89)**	(0.22,0.313,0.376)
Client Testimonials	**(0.22,0.291,0.427)**	(0.0081,0.012,0.023)
Creditworthiness and Rating	**(0.288,0.3637,0.432)**	(0.010,0.015,0.023)
References from previous clients	**(0.381,0.470,0.548)**	(0.014,0.020,0.029)

Figure 3: Computing the Normalized Fuzzy Weights Wi

Criteria	Fuzzy Weights wi	Weights Wi	Normalized Weights Wi
Sustainable Practices implemented in similar projects	(0.22,0.313,0.376)	0.303	0.295667447
Client Testimonials	(0.0081,0.012,0.023)	0.014	0.013661202
Creditworthiness and Rating	(0.010,0.015,0.023)	0.016	0.015612802

3.3 Fuzzy TOPSIS analysis

Step 1: Alternatives ratings by decision makers: A 5-point scale rating is a simple and structured way to evaluate contractors in construction projects, ranging from very low (1) to very high (5). It helps assess key factors like experience, financial stability, past performance, and compliance, making the selection process fair and data driven. The Contractors are rated by different decision makers to get a fair rating, and these ratings will be combined further for ease of calculations.

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Figure 4: Information Collected from the Decision-makers

	Sustainable Practices implemented in similar projects	Client Testimonials	Creditworthiness and Rating	References from previous clients	Project Management experience on similar projects
Contractor 1	Very low	Very High	High	Very High	High
Contractor 2	Average	Very low	Low	Very low	Low
Contractor 3	Very High	Very High	Very High	Very High	Very High

Step 2: Converting linguistic rankings to fuzzy numbers using triangular membership function: This helps turn vague ratings (like "good" or "excellent") into precise numerical values. Apply normalization techniques suitable for fuzzy data (e.g., triangular fuzzy number normalization) to ensure all criteria are on a comparable scale, regardless of their original units or scales of measurement. (Osman Taylan, 2014)

Step 3: Calculate the weighted fuzzy normalized decision matrix: Multiply each normalized fuzzy rating by the corresponding criterion weight, obtained from a previous Fuzzy AHP analysis, to reflect the relative importance of each criterion.

Table 1: Conversion of 5-point Linguistic Rating to Fuzzy Numbers

Term	Fuzzy Numbers
Very Low	(1,1,3)
Low	(1,3,5)
Average	(3,5,7)
High	(5,7,9)
Very High	(7,9,9)

Figure 5: Conversion of Linguistic Rating to Fuzzy Numbers

	Sustainable Practices implemented in similar projects	Client Testimonials	Creditworthines s and Rating	References from previous clients
Contractor 1	(1,1,1)	(5,7.67,9)	(5,7,9)	(7,9,9)
Contractor 2	(3,5,7)	(1,1,3)	(1,3.67,7)	(1,1,3)
Contractor 3	(1,7,9)	(7,9,9)	(7,9,9)	(5,5,9)

Step 4: Determine fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS): Identify the FPIS, representing the best possible performance for each criterion, and the FNIS, representing the worst possible performance. These are defined based on the maximum and minimum fuzzy values in the weighted normalized decision matrix. (Fang Wang, 2016)

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Figure 6: Calculating the Weighted Normalized Decision Matrix

Weightage	(0.22,0.313,0.376)	(0.0081,0.012,0.023)	(0.010,0.015,0.023)	(0.014,0.020,0.029)	(0.018,0.025,0.035)
	Sustainable Practices implemented in similar projects	Client Testimonials	Creditworthiness and Rating	References from previous clients	Project Management experience on similar projects
Contractor 1	(1,1,1)	(5,7.67,9)	(5,7,9)	(7,9,9)	(5,7,9)
Contractor 2	(3,5,7)	(1,1,3)	(1,3.67,7)	(1,1,3)	(1,3,5)
Contractor 3	(1,7,9)	(7,9,9)	(7,9,9)	(5,5,9)	(7,9,9)

Figure 7: Calculation of FPIS and FNIS

Weightage	(0.22,0.313,0.376)	(0.0081,0.012,0.023)
	Sustainable Practices implemented in similar projects	Client Testimonials
Contractor 1	(0.022,0.034,0.041)	(0.004,0.0102,0.023)
Contractor 2	(0.072,0.175,0.29)	(0.0008,0.0013,0.007)
Contractor 3	(0.024,0.244,0.376)	(0.006,0.012,0.023)
A+	**(0.024,0.244,0.376)**	**(0.006,0.012,0.023)**
A-	**(0.022,0.034,0.041)**	**(0.0008,0.0013,0.007)**

Figure 8: Calculating the Distance from FPIS and FNIS

Weightage	(0.22,0.313,0.376)	(0.0081,0.012,0.023)
	Sustainable Practices implemented in similar projects	Client Testimonials
Contractor 1	(0.022,0.034,0.041)	(0.004,0.0102,0.023)
Contractor 2	(0.072,0.175,0.29)	(0.0008,0.0013,0.007)
Contractor 3	(0.024,0.244,0.376)	(0.006,0.012,0.023)
A+	**(0.024,0.244,0.376)**	**(0.006,0.012,0.023)**
A-	**(0.022,0.034,0.041)**	**(0.0008,0.0013,0.007)**
Contractor 1	**0.1132**	**0.0015**
Contractor 2	**0.414**	**0.0115**
Contractor 3	**0**	**0**
Contractor 1	**0**	**0.0107**
Contractor 2	**0.1677**	**0**
Contractor 3	**0.1132**	**0.0115**

Step 5: Compute Distances from FPIS and FNIS: Calculate the distance of each contractor's performance from both the FPIS and FNIS using the vertex method or another suitable distance measure for fuzzy numbers (Fang Wang, 2016).

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Step 6: Calculate Closeness Coefficients and Rank Contractors: Determine the closeness coefficient for each contractor, representing its relative proximity to the FPIS and distance from the FNIS. Rank the contractors in descending order based on their closeness coefficients, with the highest coefficient indicating the most suitable contractor.

Figure 9: Calculation of Closeness Coefficient and Ranking

	Di+	Di-	CCi	Rank
Contractor 1	0.5461	0.2527	0.316349524	3
Contractor 2	0.7119	0.5301	0.426811594	2
Contractor 3	0.8721	1.3203	0.602216749	1

4.0 Results and Findings

Fuzzy AHP ranks contractors by integrating literature criteria, expert opinions, and project needs. Linguistic ratings are converted into fuzzy numbers, averaged to mitigate bias, and compiled into a pairwise comparison matrix. Fuzzy geometric means, such as (6.096, 7.177, 6.89) for "Sustainable Practices," and de-fuzzified scores like 3.9696 for "Risk Management capacity," provide data-driven insights. Utilizing a fuzzy scale, like (1,1,1) for "Equal" and (9,9,9) for "Extremely strong," ensures representative judgments. This approach emphasizes risk and safety in contractor selection. Fuzzy TOPSIS provides a structured ranking method using a 5-point rating scale and triangular membership functions, enhancing objectivity. A combined decision matrix, incorporating experience, financial health, and performance, enables equitable comparisons via normalized fuzzy scores. Weighting factors reflect criterion importance, leading to holistic evaluations. Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) serve as benchmarks, with closeness coefficients determining contractor rankings. These methods collectively enhance decision-making accuracy and fairness in contractor selection.

5.0 Conclusion

In conclusion, the integration of Fuzzy AHP and Fuzzy TOPSIS offers a robust and comprehensive framework for contractor selection, addressing the inherent complexities and uncertainties of the construction industry. Fuzzy AHP systematically translates subjective linguistic opinions into numerical fuzzy values, minimizing personal bias and providing a data-driven evaluation based on critical criteria like sustainability, financial health, and safety. By constructing a pairwise comparison matrix and employing the geometric mean, this method ensures a holistic and informed decision-making process, emphasizing risk management and

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safety procedures. Complementarily, Fuzzy TOPSIS facilitates fair and objective contractor ranking. Through the conversion of linguistic assessments into fuzzy numbers and the creation of normalized and weighted decision matrices, it enable equitable comparisons. Utilizing Fuzzy Positive-Ideal Solution (FPIS) and Fuzzy Negative-Ideal Solution (FNIS) as benchmarks, the closeness coefficient provides a clear ranking, guiding contractor selection. This combined methodology enhances the transparency and reliability of contractor evaluations, ultimately contributing to improved project outcomes and mitigating potential risks.

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Annexures

For further reference to the Data collection, and analysis and decision making for criteria as well as contractor selection please refer to the documents provided below.
Data Collection: https://docs.google.com/forms/d/e/1FAIpQLSdlJkJEg_7ArpI_ln_5bGE6 k6wu PWLu_G9oF0Y_T-0guZx42g/viewform
Fuzzy AHP Analysis for ranking of Selection Criteria: Fuzzy AHP.xlsx
Ranking of Contractor Using Fuzzy TOPSIS: Fuzzy TOPSIS Analysis.xlsx