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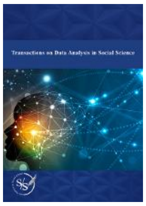

Development and Ranking of Construction Project Performance Based on Value Engineering and Fuzzy VIKOR

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ABSTRACT

Reducing project cost and duration while maintaining or enhancing quality is a fundamental objective in construction project management and one of the core missions of value engineering, which aims to optimize the functionality of systems while minimizing unnecessary expenditures. This study proposes a comprehensive performance improvement framework that integrates value engineering with the fuzzy Analytic Hierarchy Process (FAHP) and fuzzy VIKOR methodology to enhance the efficiency and effectiveness of construction projects. In the initial stage, the value engineering approach was employed to identify key performance improvement criteria through the evaluation of expert opinions, ensuring that all critical factors influencing project success were considered. In the subsequent stage, the relative importance of these criteria was quantified using fuzzy network analysis, allowing for more precise and nuanced weighting under conditions of uncertainty. Finally, the various scenarios developed during the creativity phase of the value engineering process were systematically ranked using the fuzzy VIKOR method to determine the optimal solution. The results indicate that implementing the scenario recommended by the value engineering team, as opposed to the original project design, can achieve a significant 16.3% reduction in overall project cost and a 26.42% decrease in project duration. These findings demonstrate that the integrated approach of value engineering combined with fuzzy multi-criteria decision-making provides a practical and effective strategy for improving project performance in construction management.

1. INTRODUCTION

In the project management literature, cost, time, and quality are considered the primary indicators of project performance. Today, various approaches have been developed within the domain of project management to enhance project performance. Among these, value engineering has emerged as an effective tool, particularly in the

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construction sector. The main objective of value engineering is to enhance the value of system functions under study [1].

Project design may involve unnecessary costs, as projects are often initiated and designed under the pressure of meeting deadlines, leaving designers with limited time to identify and eliminate avoidable expenses. Without conducting value management studies, unnecessary costs may remain unidentified, ultimately leading to increased project expenditures. Value management, therefore, serves as a tool to eliminate such deficiencies while ensuring maximum client satisfaction [2]. The output of the value engineering process consists of improvement proposals aimed at delivering products or outcomes more desirable for clients or stakeholders [3].

Value management is particularly beneficial for developing countries such as Nepal, where weak construction practices and a lack of key technical insights have contributed to project delays and cost overruns [4]. The effective performance of any construction project implies freedom from defects, timely delivery, and continuous improvement [5].

Furthermore, since employers in value engineering studies—especially in construction projects—often rely on subjective and imprecise judgments, fuzzy multi-criteria decision-making approaches are commonly applied at both the criteria weighting and alternative ranking stages.

This study aims to identify and analyze the factors influencing the cost and time performance of a project through the formation of a value engineering team consisting of client representatives, consultants, and contractors. The research applies the complete methodology of value engineering, integrated with fuzzy Analytic Hierarchy Process (FAHP) and fuzzy VIKOR, to evaluate and rank project improvement scenarios.

2. LITERATURE REVIEW

This section reviews key studies in project management, value engineering, and multi-criteria decision-making methods that contribute to reducing costs, shortening timelines, and improving quality.

Karimi et al. proposed a project management performance evaluation model by introducing six criteria based on the business excellence framework. These include leadership, project personnel, policy and strategy, partnerships, the project lifecycle process, and key performance indicators. Using organizations in Pakistan as case studies, the authors applied correlation analysis to validate their model and confirmed the positive and significant influence of these criteria on project performance [3].

Sarami et al. conducted a field study titled “Organizational Maturity in Project Management: A Field Study in the Engineering and Construction Firms Association.” Their investigation across nine large project-based organizations in the oil, gas, and petrochemical sectors revealed that while the importance of using reliable decision-making criteria and performance reports is well understood, structural issues, power conflicts, and authority distribution remain critical challenges [6].

Salehi et al., in a study titled “A Model for Evaluating the Management of Automotive Component Projects,” combined the classical project management triangle of time, cost, and quality with a customer-oriented performance evaluation approach. Using factor analysis, they identified key underlying dimensions shaping evaluation criteria and developed a model tested through questionnaires. Their results highlighted a lack of proper risk management as a significant factor negatively affecting project success [7].

Farhamandian et al., in their study “Evaluation of Gas Supply Projects Using PMBOK: A Case Study of Zanjan Gas Company,” introduced a practical model to assess organizational adherence to project management standards. The model was implemented as a case study in gas supply projects within the Zanjan Gas Company [8].

Frank et al. focused on project review and evaluation to identify project management competencies by utilizing PMBOK standards and lessons learned from past projects. Their analysis, supported by the Analytic Hierarchy Process (AHP), emphasized prioritizing core project management competencies across initiation, planning, execution, monitoring, and closure phases [9].

Lin, in his study on critical success factors for urban redevelopment projects in Korea, employed brainstorming with 29 experts, followed by a survey of 120 specialists. Statistical analyses, including t-tests, led to the identification and prioritization of ten key success factors [10].

Kebik et al. analyzed green space project success factors in the United Kingdom using the General Organizational Logic Framework. Data from projects between 1996 and 2000 were assessed using variance analysis, revealing that stakeholder engagement, knowledge management, and performance cycle support were critical success determinants [11].

Tseng et al. proposed a multi-criteria decision-making model for project performance evaluation inspired by PMBOK. Their approach assessed domains such as cost, quality, human resources, communications, risk, and procurement, integrating expert opinions and sensitivity analysis to prioritize project criteria [12].

Najafi et al. applied the Analytic Network Process (ANP) to analyze structural and environmental challenges in project management. Their validation within Alupen Company confirmed the robustness of ANP for identifying strategic project factors [13].

Madashika et al. investigated key performance indicators (KPIs) of value engineering in Sri Lanka’s construction industry through a mixed-method approach. Findings indicated that the preliminary design stage was the most appropriate phase for implementing value engineering [14].

Saterina et al. examined the potential adoption of value engineering in Spain’s construction industry, highlighting the role of environmental uncertainty as a driver for strategic adoption to maintain long-term competitiveness [15].

Abdulbasit et al. addressed decision-making under uncertainty in project selection by combining the Neutrosophic Set Theory with DEMATEL and TOPSIS. Their method identified project criteria through DEMATEL and ranked alternatives using TOPSIS [16].

Finally, Gala et al. introduced a regression-based and structural equation modeling (SEM) approach for redesigning products and reducing costs through value engineering. Their findings demonstrated how redesign, cost reduction, and component substitution enhance product quality and performance while lowering expenses [17].

3. METHODOLOGY

The present study adopts a descriptive research design, and within the descriptive category, it is conducted as a case study. The research is based on the standard model developed by the Society of American Value Engineers (SAVE International), commonly referred to as the Value Engineering (VE) methodology.

3.1. Problem Description

In civil construction projects, whether small-scale or large-scale, the increase in cost and time represents one of the major challenges faced by clients. In this study, the construction project of a school was implemented according to the principles and standards of Value Engineering. The weights of the evaluation criteria were first determined using the Fuzzy Analytic Hierarchy Process (FAHP). Subsequently, in the stage of selecting the most critical criteria, the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method was employed.

3.2. Stages of Value Engineering

This section outlines the different stages of applying the Value Engineering methodology in the construction project under study.

3.2.1. Pre-Study Phase

The main evaluation criteria, identified during the initial session with the client, include:

- Feasibility of implementation
- Maintainability and ease of repair

- Reliability
- Service life

To determine the relative weights of these criteria, the Fuzzy Analytic Hierarchy Process (FAHP) with an extent analysis approach was applied. Specifically, the geometric mean of the triangular fuzzy numbers assigned by each team member was computed. This aggregation represents the collective judgment of the Value Engineering team. The calculation was performed using the following formula:

$$\left[\prod_{k=1}^{n} \tilde{a}_{ij}^{k}\right]^{\frac{1}{n}} \quad i=1,2,3,\ldots, m \quad j= 1,2,3,\ldots,m \qquad (1)$$

In Table 1, the fuzzy AHP pairwise comparison matrix, obtained from the geometric mean of the experts' opinions, is presented.

Table 1. Pairwise Comparison Matrix of Criteria (Fuzzy AHP)

Criterion	**C1**	**C2**	**C3**	**C4**
C1	(1.000, 1.000, 1.000)	(1.023, 1.201, 1.394)	(0.909, 1.201, 1.565)	(1.178, 1.442, 1.732)
C2	(0.717, 0.833, 0.977)	(1.000, 1.000, 1.000)	(0.734, 0.953, 1.267)	(0.749, 0.933, 1.149)
C3	(0.639, 0.833, 1.100)	(0.789, 1.049, 1.362)	(1.000, 1.000, 1.000)	(1.073, 1.348, 1.642)
C4	(0.577, 0.693, 0.849)	(0.870, 1.072, 1.335)	(0.609, 0.742, 0.932)	(1.000, 1.000, 1.000)

The next step involves calculating the weight vector derived for each of the evaluation criteria. These weights represent the relative importance of each criterion in assessing the proposed alternatives.

W = [0.344 , 0.206 , 0.276 , 0.174]T

Accordingly, the mechanical installations subsystems were selected as the subject of study and the scope of the value engineering analysis. Based on the bill of quantities (BOQ) and the estimated total cost of the project obtained during the information-gathering stage, the estimated cost of each subsystem was extracted according to the initial design. Likewise, the critical path duration for each subsystem was identified using the project schedule developed in MSP software. As a result, the heating subsystem was chosen as the focus of the study.

3.2.2. Main Study Phase

1. Information Sub-phase:
   During the review of the initial design by experts, the detailed specifications of the heating subsystem were identified.
2. Functional Analysis Sub-phase:
   The value index was used to determine the priority of each function for further study, i.e., the creativity phase.
3. Creativity Sub-phase:
   In this session, the principles of brainstorming were followed to generate and select alternative scenarios.

3.2.2.1. Evaluation Sub-phase:

To gather the opinions of each member of the value engineering team regarding the relative importance of the proposed scenarios with respect to each criterion, linguistic variables represented by membership functions were employed. Subsequently, the arithmetic mean of triangular fuzzy numbers corresponding to the importance of each scenario under each criterion was calculated.

Table 2. Proposed Scenarios by the Value Engineering Team

Scenario	ID	Proposed Alternative
Scenario A1	D1	Use of plastic foam insulation
	D2	Use of double angles in supports
	D3	Use of plastic clamps
	D4	Use of multilayer pipes inside units
Scenario A2	D1	Use of plastic foam insulation
	D2	Use of double angles in supports
	D5	Integration of risers
	D6	Use of multilayer pipes inside units
Scenario A3	D1	Use of plastic foam insulation
	D2	Use of double angles in supports
	D3	Use of plastic clamps
Scenario A4	D1	Use of plastic foam insulation
	D2	Use of double angles in supports
	D5	Integration of risers
	D6	Use of multilayer pipes inside units
Scenario A5	D1	Use of plastic foam insulation
	D3	Use of double angles in supports
	D7	Direct piping system in basements

Table 3. Fuzzy Decision Matrix

	c1			**c2**			**c3**			**c4**		
A1	5	6.833	8.333	7	8.667	9.667	3.833	5.667	7.5	1.333	2.833	4.667
A2	6.333	8.333	9.333	5.333	7.167	8.667	3.167	5	6.833	3.667	6	7.5
A3	3.333	5.333	7.176	2.833	4.667	6.667	1.333	2.833	4.667	0.333	1.333	2.333
A4	1.333	2.8333	4.333	2.167	4	6	2.833	4.667	6.167	1.667	2.667	4
A5	2.5	4.333	6	1.833	3.667	5.333	2	3.667	5.333	3.167	5	6.5

Table 4. Normalized Fuzzy Decision Matrix

	c1			**c2**			**c3**			**c4**		
A1	0.536	0.732	0.893	0.724	0.9	1	0.511	0.756	1	0.178	0.378	0.622
A2	0.679	0.893	1	0.552	0.74	0.9	0.422	0.667	0.91	0.489	0.8	1
A3	0.357	0.571	0.768	0.293	0.48	0.69	0.178	0.378	0.62	0.044	0.178	0.311
A4	0.143	0.304	0.464	0.224	0.41	0.62	0.378	0.622	0.82	0.156	0.356	0.533
A5	0.268	0.464	0.643	0.19	0.38	0.55	0.267	0.489	0.71	0.422	0.667	0.867

The aggregation of the experts' opinions results in the fuzzy decision matrix, which is presented in Table 3. Subsequently, the normalized fuzzy decision matrix is calculated and multiplied by the weight vector of the criteria obtained through the fuzzy AHP method, as shown in Table 4. Thereafter, the relative closeness index of each alternative is computed. The ranking of the alternatives (scenarios) is determined based on the descending order of the relative closeness index. Table 5 presents the values of the relative closeness index and the corresponding ranking of each alternative using the fuzzy VIKOR method.

Table 5. Relative Closeness Index and Ranking of Alternatives Using the Fuzzy VIKOR Method

Rank	Q Index	Alternative
2	2.544785	A1
1	1.21818	A2
3	2.964215	A3
5	4.759576	A4
4	3.287243	A5

Accordingly, based on the above table, Scenario A2 was selected as the proposed scenario by the value engineering team for the heating system of the studied project.

3.2.2.2. Development Sub-phase

In the development phase, the best idea selected in the evaluation phase is refined and elaborated to prepare the final value engineering proposals. In the present study, the value engineering team estimated Scenario A2 and compared it with the costs and durations associated with the proposed plan.

3.2.2.3. Presentation Sub-phase

At the end of the main study phase, the value engineering proposal, along with technical drawings, specifications, and results derived from the value study and cost and time estimates, was presented to the project owner.

4. CONCLUSION

Cost, time, and quality are considered the primary indicators of project performance. According to the estimates of the value engineering team, the implementation of the proposed scenario resulted in a 16.3% reduction in the cost of the studied subproject compared to the initial plan. The critical path duration of the subproject was also reduced by 26.42%. Accordingly, the total project cost decreased by 6.8%, and the total project critical path duration decreased by 8.9%. Therefore, it can be concluded that applying value engineering using the approach proposed in this study can effectively improve the performance of the studied subproject.

Transparency Statement

The data supporting this study are available upon reasonable request to the corresponding author, subject to ethical and confidentiality considerations.

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Declaration of Interest

The authors declare that they have no competing interests.

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REFERENCES

[1] Heuer, T., & Runde, J. (2021). The Elbphilharmonie and the Hamburg effect: On the social positioning, identities and system functions of a building and a city. *European Planning Studies, 30*(1), 85–104. https://doi.org/10.1080/09654313.2021.1908232

[2] Mishra, A. (2019). Implementation status of value management in project management practice in Nepal. *International Journal of Management Studies, 6*(1), 92. https://doi.org/10.18843/ijms/v6i1(1)/13

[3] Karimi, M. (2008). *Undoubted improvement: Practical training in value engineering* (2nd ed.). Tehran: Rasa Cultural Services Institute.

[4] Malla, S. (2013). *Application of value engineering in Nepalese building construction industry* (Master's thesis). Asian Institute of Technology, Thailand.

[5] Chiluwal, K., & Mishra, A. K. (2018). Impact of performance on profitability of small hydropower projects in Nepal. *International Journal of Current Research, 10*(1), 63918–63925.

[6] Saremi, M., Ebtehaj, M., & Afshari, H. R. (2009). Organizational maturity in project management: A field study in the association of engineering and construction companies. *Business Management Studies, 1*(1), 45–59.

[7] Salehi, M., Saeedi Mehrabad, M., & Seyed Hosseini, S. M. (2009). A model for evaluating project management in automotive parts construction and assessment of results. *International Journal of Industrial Engineering and Production Management (Persian), 20*(2), 31–43.

[8] Farahmandian, A., Mousikhani, M., & Mansouri, A. (2009). Evaluation of gas supply project management using PMBOK: Case study of Zanjan Gas Company. *Industrial Management Journal (Persian), 4*(9), 31–45.

[9] Anbari, F. T., Carayannis, E. G., & Voetsch, R. J. (2008). Post-project reviews as a key project management competence. *Technovation, 28*, 633–643. https://doi.org/10.1016/j.technovation.2007.12.001

[10] Lin, Y.-H., et al. (2009). Research on using ANP to establish a performance assessment model for business intelligence systems. *Expert Systems with Applications, 36*, 4135–4146. https://doi.org/10.1016/j.eswa.2008.03.004

[11] Cebeci, U. (2009). Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. *Expert Systems with Applications, 36*, 8900–8909. https://doi.org/10.1016/j.eswa.2008.11.046

[12] Tseng, M.-L. (2010). Implementation and performance evaluation using the fuzzy network balanced scorecard. *Computers & Education, 55*, 188–201. https://doi.org/10.1016/j.compedu.2010.01.004

[13] Najafi, A. (2019). Applying analytic network process (ANP) in analyzing structural challenges and organizational execution environment in project management. *International Journal of Industrial Engineering and Production Management (Persian), 21*(1), 63–76.

[14] Madushika, W. H. S., Perera, B. A. K. S., Ekanayake, B. J., & Shen, G. Q. P. (2018). Key performance indicators of value management in the Sri Lankan construction industry. *International Journal of Construction Management*. https://doi.org/10.1080/15623599.2018.1484556

[15] Sutrisna, M., Pellicer, E., Torres-Machi, C., & Picornell, M. (2018). Exploring earned value management in the Spanish construction industry as a pathway to competitive advantage. *International Journal of Construction Management*. https://doi.org/10.1080/15623599.2018.1459155

[16] Abdel-Basset, M., Atef, A., & Smarandache, F. (2019). A hybrid neutrosophic multiple criteria group decision

making approach for project selection. *Cognitive Systems Research, 57*, 216–227. https://doi.org/10.1016/j.cogsys.2018.10.023

[17] Galaa, P., Zirena, P., & Arredondo, A. (2020). Product redesigning, cost reduction, component substitution, and their influence in value management in micro and small enterprises. *Management Science Letters, 10*, 1277–1286. https://doi.org/10.5267/j.msl.2019.11.030