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Presenting A Framework To Evaluate Suppliers Of Construction Materials Supply Chain Using Sustainable Development Factors

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Abstract:

The construction industry is a major consumer of resources and a significant source of environmental and social impacts, making sustainable procurement an important managerial concern. Supplier selection for construction materials is a complex multi-criteria decision-making problem, particularly in project-based environments characterized by cost pressure, uncertainty, and time constraints. Although sustainable supplier selection has been widely studied, there is still a need for context-specific and operational frameworks applicable to construction material procurement. This study proposes an integrated decision-support framework for evaluating construction material suppliers based on sustainability criteria. The framework combines Fuzzy Delphi, Best-Worst Method (BWM), and Fuzzy TOPSIS. First, 30 experts from academia and industry participated in a Fuzzy Delphi process to identify and screen 27 sustainability indicators relevant to construction procurement. Experts were selected based on professional experience, involvement in procurement or sustainability-related decisions, and relevant academic or managerial qualifications. BWM was then applied to determine the relative importance of the criteria, and Fuzzy TOPSIS was used to rank supplier alternatives. The results indicate that the economic dimension received the highest priority (0.5431), followed by the social (0.2693) and environmental (0.1876) dimensions. Among the evaluated alternatives, Supplier 2 achieved the highest closeness coefficient (0.63) and ranked as the most suitable supplier. This study contributes by developing a practical and context-specific framework for sustainable supplier selection in the construction materials supply chain. The framework can support procurement decision-making in construction and housing projects while promoting sustainability objectives.

1. Introduction

Supplier selection is a critical, multi-dimensional process that dictates how organizations secure strategic partners to enhance competitive advantage and project delivery efficiency [1]. In the specialized field of Construction Project Management, selecting the right material supplier requires addressing two core challenges: the identification of robust, industry-specific criteria and the application of rigorous methodologies to evaluate alternatives under uncertainty. Weber et al. [2] highlighted that the complexity of procurement decisions necessitates diverse criteria and sophisticated analytical approaches.

Since the 1960s, these challenges have drawn significant attention from both academic researchers and legal experts in the procurement domain [3]. In today's landscape of rapid technological shifts and intense market competition, construction firms must adopt agile strategies to remain resilient. Contemporary studies [5] argue that no firm can operate effectively in isolation; market pressures have transformed Supply Chain Management (SCM) into a cornerstone of corporate survival. A well-integrated supply chain is no longer just a logistical necessity but a primary driver of business sustainability and a decisive competitive edge [6]. Consequently, the evaluation and selection of suppliers aim to identify partners who can meet the purchaser's requirements in terms of quality, time, and cost-efficiency at the highest professional standards [7]. In most

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industrial sectors, particularly in construction, the procurement of raw materials and components represents a dominant portion of total project costs, often ranging between 70% to 80% [2]. Therefore, procurement strategies and operations play a decisive role in the financial viability and profitability of any construction venture. Suppliers are not merely external vendors; they are integral components of the project lifecycle. Their performance can have profound impacts on the overall success of the organization. Research shows that many quality failures in construction are traced back to defective materials; thus, the accurate selection of competitive suppliers is essential to mitigate risks and maximize the quality of the built environment [8]. Recent advancements (2024-2025) further emphasize that incorporating Circular Economy (CE) principles into material selection is vital for long-term resource efficiency and waste reduction [9]. Despite the wealth of general SCM literature, a significant Research Gap exists regarding the development of localized sustainable development frameworks specifically for the Construction Material Supply Chain (CMSC). General models often fail to account for the unique, project-based nature of construction or the specific economic constraints of regional markets [10]. For instance, traditional environmental metrics such as RoHS or WEEE, while standard for electronics, are inapplicable to bulk construction materials like cement or steel. In a dynamic and volatile environment, construction organizations need high resiliency to manage material and information flows effectively. Since the timely supply of materials is critical to maintaining project schedules, there is an urgent need for an integrated, structured organization for supplier selection that creates tangible value for the customer [11]. The Novelty of this research lies in its dual contribution: first, the development of a context-aware framework that localizes 27 sustainability indicators through a Fuzzy Delphi process, and second, the application of a hybrid FDM-BWM-Fuzzy TOPSIS methodology to a real-world case study. Fuzzy Delphi was employed for expert-based screening of localized criteria under ambiguity, BWM was adopted because it requires fewer pairwise comparisons and offers higher consistency than AHP-like methods, and Fuzzy TOPSIS was used because supplier evaluation involves vagueness and the need to rank alternatives based on closeness to an ideal solution. The construction supply chain is inherently fragmented and time-constrained, making long-term integration difficult. However, if governmental bodies and agent banks, such as Maskan Bank, focus on identifying and employing these critical success factors [12], they can substantially reduce overall construction costs [13]. Methodologically, this study adopts the Best-Worst Method (BWM) as a core component, as it provides a more robust and efficient alternative to traditional MCDM tools by significantly reducing the number of pairwise comparisons and enhancing consistency [14]. By combining BWM with Fuzzy TOPSIS, this research provides a comprehensive and practically applicable model for evaluating construction material suppliers. The primary objective is to present a structured framework that prioritizes localized sustainable development factors across economic, social, and environmental dimensions, ensuring that procurement decisions align with both financial profitability and global sustainability mandates. The novelty of this study lies not in the proposal of a new MCDM algorithm, but rather in the development of a context-specific, localized framework for sustainable supplier selection in the construction materials supply chain. While previous studies have often relied on generic industrial indicators, this research identifies and validates 27 sustainability criteria specifically tailored to the Iranian construction sector (Maskan Bank projects) through a multi-stage FDM-BWM-Fuzzy TOPSIS approach. This study bridges the gap between theoretical sustainability goals and practical procurement constraints in high-stakes housing projects. This study does not propose a new mathematical method, its contribution is a context-specific decision-support framework the novelty lies in indicator localization, not in inventing a new algorithm (Table 1).

Table 1: A review of the most recent studies in the construction material supply chain.

Reference	Subject under investigation	Problem-solving approach			Sustainability considerations		
		MP (Mathematical Planning)	**MCDM (Multi-criteria decision-making)**	**Others**	**E (Economic)**	**N (Environmental)**	**S (Social)**
Peykani, P., Emrouznejad, A., Nouri, M., et al.. [14]	Best-worst multi-criteria decision-making method: A review of the literature. Socio-Economic Planning Sciences	-	BWM	-	■	-	-

Vo, K. D., Le, T. D. C., Nguyen, D. D., et al. (2026 [15]	). An interval type-2 fuzzy TOPSIS approach for green supplier selection in sustainable construction	-	Fuzzy Topsis	-	■	■	■
Gunduz, M., & Almuajebh, M. [11]	Critical Success Factors for Sustainable Construction Project Management. Sustainability		AHP		■	■	■
Rezaei. [4]	Best-worst multi-criteria decision-making method		BWM		■	■	■
Asaad, A., & El-Sayegh, S. M. [36]	). Key criteria for selecting green suppliers for construction projects in the UAE. Journal of Financial Management of Property and Construction,	-	AHP	-	-	■	■
Li, Y. Deng, J., Wang, Y., et al. [9]	The Condition Evaluation of Bridges Based on Fuzzy BWM and Fuzzy Comprehensive Evaluation. Applied Sciences,	-	-	Structural equation modeling	■	■	■
Golpîra [17]	Optimizing the issue of locating the facility and designing the construction supply chain network	■	-	-	■	-	-
Ghamari, H., Abbasianjahromi, H., Mirhosseini, S. M., et al. (2024)[37]	). Providing a framework to optimize the sustainable construction material supply chain with the possibility of horizontal transfers. Sustainable Futures,		MCDM				
Sun, Y., Zhu, S., Wang, D., et al. (2024).. [38]	Global supply chains amplify economic costs	■	-	-	■	■	-

	of future extreme heat risk. Nature,						
Liang, R., Li, R., Yan, X., et al. (2023).[39]	Evaluating and selecting the supplier in prefabricated megaprojects using extended fuzzy TOPSIS under hesitant environment: A case study from China..	-	GRA TOPSIS	-	■	■	■
Singh, A., Kumar, V., Verma, P., et al. (2025).. [40]	Sustainable supplier selection in a construction company: A new MCDM method based on dominance-based rough set analysis.	-	MCDM	-	■	■	■
Feng, C., Ma, Y., Zhou, G., et al. (2018).. [24]	Stackelberg game optimization for integrated production-distribution-construction system in construction supply chain.	■	-	-	■	-	-
Mathiyazhagan et al. [41]	Identifying and prioritizing motivational factors for the green supply chain management	-	AHP	-	■	■	-
Chen et al. [18]	Selecting suppliers and scheduling construction projects	■	-	-	■	-	-
Lin et al. [28]	Optimizing the sustainable construction supply chain based on incentives	■	-	-	■	■	■
Yang et al. [29]	Placing an order in the supply chain for prefabricated building materials			Genetic algorithm	■	-	-
Cao et al. [30]	Selecting suppliers of construction materials with low-carbon production	-	TOPSIS	-	■	■	-

Jaśkowski et al. [31]	Material supply channel planning	■	-	-	■	-	-
Seth et al. [32]	The effect of competitive conditions on the supplier evaluation process	-	■	-	■	-	-
Wibowo et al. [33]	Investigating the factors implementing green supply chain management in the construction industry	-	-	Delphi method	■	■	-

2. Method

This study falls under purposeful and descriptive-survey research. To develop the theoretical framework and provide a comprehensive literature review, the library method was employed. The statistical population consists of 30 experts from various industrial and academic domains. The expert panel was selected using purposive sampling, supplemented by snowball referrals to access highly experienced specialists in sustainable construction supply chains. This sampling method was chosen due to the specialized nature of the subject and the need for access to experts with high-level experience in sustainable construction supply chains. The expert panel includes three distinct groups: (1) academic professors with expertise in sustainable development and civil engineering, (2) managers and senior technical experts from commercial and technical bureaus of construction-related organizations, and (3) professional consultants and instructors specializing in supply chain selection processes.

To ensure methodological rigor and address the complexities of supplier evaluation, a hybrid multi-criteria decision-making (MCDM) approach consisting of **Fuzzy** Delphi, BWM, and Fuzzy TOPSIS was implemented. This integration enables the framework to capturing human subjectivity and uncertainty while maintaining a high level of consistency in decision-making. The research process was conducted in four distinct stages (Fig. 1):

1. Stage 1: Identification of initial sustainable development indicators through an extensive literature review.
2. Stage 2: Screening and localization of indicators using the Fuzzy Delphi Method (FDM) to ensure context-relevance for the construction material supply chain.
3. Stage 3: Calculating the weights of the finalized indicators using the Best-Worst Method (BWM).
4. Stage 4: Ranking the construction material suppliers using the Fuzzy TOPSIS technique.

detailed information for the final ranking phase.

Data collection was facilitated through specialized questionnaires: a Fuzzy Delphi questionnaire for indicator screening, BWM pairwise comparison forms, and semi-structured interviews to obtain

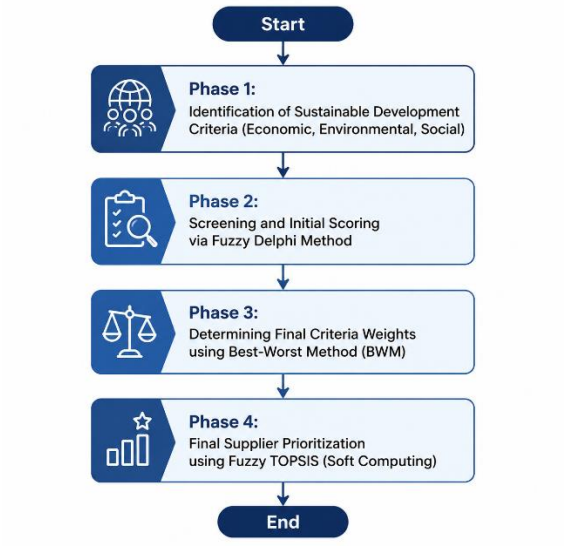


Fig. 1: Research method step-by-step structure

Table 2: Seven verbal fuzzy variables

Verbal variable	English equivalent	Fuzzy number
Absolutely important	EI	(0.9,1,1)
Relatively important	VI	0.75,0.9,1)
Important	I	(0.5,0.75,0.9)
Almost important	MI	0.3,0.5,0.75)
Unimportant	U	(0.1,0.3,0.5)
Relatively unimportant	VU	(0,0.1,0.3)
Absolutely unimportant	EU	(0.0,0.1)

2.1. Fuzzy Delphi Method (FDM)

The FDM was conducted in four iterations: identifying indicators, collecting expert opinions, screening indicators, and reaching consensus. This study utilized triangular fuzzy numbers as presented in Table 2 to handle the linguistic uncertainty of expert judgments. To ensure the reliability of the screening process, the difference between expert views and the group average was monitored across rounds. A threshold of less than 0.2 for the difference in all criteria was established as the formal stopping condition for the Delphi rounds, ensuring statistical consensus among the 30 experts.

2.2. Best–Worst Method (BWM)

The BWM, proposed by Rezaei (2015) [4], was selected over traditional methods such as AHP or ANP because it significantly reduces the number of required pairwise comparisons ($2n-3$ vs. $n(n-1)/2$). This reduction minimizes respondent fatigue and substantially lowers the inconsistency rate in expert judgments. In this study, a subset of five highly experienced experts from the primary panel was selected to perform the BWM comparisons. The indicators were organized into a hierarchical structure, and for each level, experts identified the "Best" (most important) and "Worst" (least important) criteria.

The optimal weights were derived by solving the linear programming formulation of BWM, which ensures that the maximum absolute differences between the ratios of weights and the corresponding expert judgments are minimized. To ensure the reliability of the results, the Consistency Ratio **(ξ)** was monitored for each expert's matrix; all judgments achieved a high level of consistency, indicating a reliable consensus on the criteria's relative importance. The final weights across the experts were aggregated using the geometric mean, and the global weights were calculated by multiplying the local weights across the hierarchical levels.

2.3. Fuzzy TOPSIS Method

The Fuzzy TOPSIS method was employed to rank the suppliers by measuring their proximity to the fuzzy ideal solution. Recognizing that human thinking is inherently associated with uncertainties that affect decision-making, linguistic variables represented by fuzzy numbers were used to evaluate decision matrices and criteria weights. This removes the limitations of classic TOPSIS which relies on exact values. This study adopts the fuzzy scales provided in Table 3**,** based on the established TOPSIS framework.

Table 3: Seven verbal fuzzy variables.

Verbal variable	English equivalent	Fuzzy number
Very weak	VP	(0,1,2)
Weak	P	(1,2,3)
Moderately weak	MP	(2,3.5,5)
Moderate	F	(4,5,6)
Moderately good	MG	(5,6.5,8)
Good	G	(7,8,9)
Very good	VG	(8,9,10)

3. Results

This section deals with experts' characteristics, such as age, gender, and education level. The findings are provided in Table 4.

Table 4: Experts' demographic characteristics.

Variable	Variable levels	Frequency	%
Gender	Male	30	**100%**
Age	30-35 years	0	**0%**
	35-40 years	9	**30%**
	Over 40 years	21	**70%**
Education	B.A.	6	**20%**
	M.A.	18	**60%**
	PhD	**6**	**20%**

The expert panel consisted of 30 professionals, all of whom were male. While this reflects the current demographic dominance of senior executive and technical positions in the Iranian construction supply chain industry, the selection was strictly based on meritocratic criteria, including a minimum of 10 years of field experience and holding postgraduate degrees.

3.1. Delphi Technique

In this section, all the indicators determined in the third section were first sent to the experts. These indicators are presented in Table 5.

Experts were required to consider all the sub-criteria extracted based on verbal variables. First, expert responses were collected based on fuzzy verbal variables. After collecting the first-round variables, the difference between the expert views and their average views was sent to them. Then, they were asked to announce their views again. Later, new experts' views and the differences between their opinion in the first and second stages were examined. Table 6 presents the differences in expert views between the first and second rounds. A difference of less than 0.2 in all criteria is the condition to stop all fuzzy Delphi processes. (Tables 6, 7)

Table 5: Initial dimensions and components extracted**.**

Indicators	Sub-criteria	Identifier	References
Economic	Costs/prices	E1	Matić et al. [22]
	Quality	E2	Matić et al. [22]
	Delivery	E3	Matić et al. [22]
	Resilience	E4	Matić et al. [22]
	Technological capability	E5	Matić et al. [22]

	Affordability/financial ability	E6	Matić et al. [22]
	Participation relations	E7	Matić et al. [22]
	Transportation costs	E8	Gurel et al. [34]
	Adaptation with strategic sectoral pricing	E9	Gurel et al. [34]
	Purchase of environmentally friendly materials	E10	Gurel et al. [34]
Social	Prestige/fame	S1	Matić et al. [22]
	Safety and health at the working place	S2	Matić et al. [22]
	Employee pay	S3	Matić et al. [22]
	Local community influence	S4	Matić et al. [22]
	Employee training	S5	Matić et al. [22]
	Respect for rights and policies	S6	Matić et al. [22]
	Information disclosure	S7	Matić et al. [22]
	Reliability	S8	Sun et al. [38]
	Technical assistance and support	S9	Sun et al. [38]
Environmental	Green image	N1	Matić et al. [22]
	Environment protection management system	N2	Matić et al. [22]
	Pollution control	N3	Matić et al. [22]
	Green products	N4	Matić et al. [22]
	ECO design	N5	Matić et al. [22]
	Resource consumption	N6	Matić et al. [22]
	Green competence	N7	Matić et al. [22]
	Using harmful/ detrimental materials	N8	Gurel et al. [34]
	EUP	N9	Gurel et al. [34]
	ISO 14001	N10	Gurel et al. [34]
	ODC	N11	Gurel et al. [34]
	RoHS	N12	Gurel et al. [34]
	WEEE	N13	Gurel et al. [34]
	Green packaging	N14	Gurel et al. [34]

The selected criteria and sub-criteria, together with their supporting references, are presented in Table 5. These indicators were identified through an extensive review of the relevant literature and were subsequently refined based on the characteristics of sustainable supplier evaluation in construction project management. It should be noted that some environmental indicators, such as RoHS, WEEE, and EUP, were considered in relation to suppliers of electrical, mechanical, and energy-consuming building components, which are increasingly used in modern construction projects. Therefore, their inclusion is consistent with the sustainability requirements of contemporary construction supply chains.

Table 6: Results of the average difference of experts' views in the first and second rounds.

Components	Average fuzzy of the first-round expert opinions			Definitive value of the first round	Average fuzzy of the second-round expert opinions			Definitive value of the second round	Difference level
E1	0.76	0.91	0.98	0.89	0.83	0.95	0.98	0.93	-0.04
E2	0.79	0.93	0.98	0.91	0.73	0.87	0.95	0.86	0.05
E3	0.72	0.86	0.93	0.84	0.83	0.95	0.97	0.92	-0.08
E4	0.76	0.91	0.98	0.89	0.75	0.89	0.96	0.87	0.02
E5	0.85	0.97	0.99	0.94	0.84	0.96	0.98	0.93	0.01
E6	0.86	0.98	0.99	0.95	0.79	0.91	0.95	0.89	0.06
E7	0.76	0.91	0.98	0.89	0.76	0.89	0.95	0.88	0.01
E8	0.21	0.26	0.37	0.28	0.00	0.02	0.13	0.04	0.24
E9	0.70	0.84	0.92	0.82	0.73	0.86	0.93	0.85	-0.02
E10	0.71	0.86	0.94	0.84	0.76	0.89	0.96	0.87	-0.04
S1	0.74	0.89	0.96	0.87	0.77	0.89	0.95	0.87	-0.01
S2	0.75	0.90	0.97	0.88	0.83	0.94	0.97	0.92	-0.04
S3	0.85	0.97	0.99	0.94	0.84	0.96	0.98	0.93	0.01
S4	0.85	0.97	0.99	0.94	0.79	0.91	0.95	0.89	0.05
S5	0.74	0.89	0.96	0.87	0.80	0.93	0.98	0.91	-0.04
S6	0.77	0.90	0.97	0.89	0.84	0.96	0.99	0.94	-0.05
S7	0.85	0.97	0.99	0.94	0.85	0.95	0.97	0.93	0.01
S8	0.74	0.88	0.95	0.86	0.76	0.90	0.96	0.88	-0.01

S9	0.85	0.97	0.99	0.94	0.80	0.91	0.94	0.89	0.06
N1	0.85	0.97	0.99	0.94	0.83	0.94	0.96	0.92	0.03
N2	0.77	0.90	0.97	0.88	0.76	0.90	0.96	0.88	0.01
N3	0.77	0.90	0.97	0.89	0.80	0.93	0.97	0.90	-0.02
N4	0.82	0.94	0.99	0.92	0.83	0.94	0.97	0.92	0.00
N5	0.82	0.94	0.99	0.92	0.83	0.94	0.97	0.92	0.00
N6	0.81	0.94	0.99	0.92	0.83	0.94	0.97	0.92	0.00
N7	0.22	0.27	0.37	0.28	0.01	0.04	0.16	0.06	0.22
N8	0.84	0.96	0.99	0.94	0.88	0.99	1.00	0.96	-0.02
N9	0.01	0.03	0.15	0.05	0.00	0.02	0.13	0.04	0.01
N10	0.78	0.92	0.98	0.90	0.81	0.94	0.98	0.92	-0.02
N11	0.01	0.04	0.16	0.06	0.01	0.05	0.17	0.07	-0.01
N12	0.31	0.37	0.47	0.38	0.02	0.08	0.23	0.10	0.28
N13	0.21	0.26	0.37	0.27	0.01	0.04	0.17	0.06	0.21
N14	0.76	0.91	0.97	0.88	0.80	0.94	0.98	0.91	-0.03

Table 7: Results of the average difference between the second and third rounds of expert views.

Components	**Average fuzzy of the second-round expert opinions**			**Definitive value of the second round**	**Average fuzzy of the third-round expert opinions**			**Definitive value of the third round**	**Difference level**
E1	0.83	0.95	0.98	0.93	0.83	0.95	0.98	0.93	0.00
E2	0.73	0.87	0.95	0.86	0.74	0.88	0.95	0.86	-0.01
E3	0.83	0.95	0.97	0.92	0.78	0.90	0.95	0.88	0.04
E4	0.75	0.89	0.96	0.87	0.73	0.88	0.95	0.86	0.01
E5	0.84	0.96	0.98	0.93	0.82	0.94	0.97	0.92	0.02
E6	0.79	0.91	0.95	0.89	0.78	0.91	0.96	0.89	0.00
E7	0.76	0.89	0.95	0.88	0.74	0.87	0.95	0.86	0.02
E8	0.00	0.02	0.13	0.04	0.08	0.12	0.23	0.14	-0.10
E9	0.73	0.86	0.93	0.85	0.70	0.84	0.92	0.82	0.02
E10	0.76	0.89	0.96	0.87	0.72	0.86	0.95	0.85	0.03
S1	0.77	0.89	0.95	0.87	0.75	0.88	0.94	0.87	0.01
S2	0.83	0.94	0.97	0.92	0.82	0.94	0.97	0.91	0.01
S3	0.84	0.96	0.98	0.93	0.88	0.99	1.00	0.96	-0.03
S4	0.79	0.91	0.95	0.89	0.85	0.96	0.99	0.94	-0.05
S5	0.80	0.93	0.98	0.91	0.77	0.91	0.97	0.89	0.02
S6	0.84	0.96	0.99	0.94	0.80	0.94	0.98	0.91	0.02
S7	0.85	0.95	0.97	0.93	0.85	0.97	0.99	0.94	-0.01
S8	0.76	0.90	0.96	0.88	0.75	0.88	0.95	0.86	0.01
S9	0.80	0.91	0.94	0.89	0.85	0.97	0.99	0.94	-0.06
N1	0.83	0.94	0.96	0.92	0.85	0.97	0.99	0.94	-0.03
N2	0.76	0.90	0.96	0.88	0.74	0.89	0.96	0.87	0.01
N3	0.80	0.93	0.97	0.90	0.78	0.91	0.97	0.89	0.01
N4	0.83	0.94	0.97	0.92	0.83	0.95	0.98	0.93	-0.01
N5	0.83	0.94	0.97	0.92	0.85	0.96	0.99	0.94	-0.02
N6	0.83	0.94	0.97	0.92	0.84	0.96	0.98	0.93	-0.01
N7	0.01	0.04	0.16	0.06	0.07	0.11	0.22	0.13	-0.07
N8	0.88	0.99	1.00	0.96	0.89	0.99	1.00	0.97	-0.01
N9	0.00	0.02	0.13	0.04	0.05	0.07	0.19	0.10	-0.05
N10	0.81	0.94	0.98	0.92	0.79	0.92	0.97	0.90	0.02
N11	0.01	0.05	0.17	0.07	0.03	0.08	0.20	0.10	-0.02
N12	0.02	0.08	0.23	0.10	0.02	0.08	0.23	0.10	0.00
N13	0.01	0.04	0.17	0.06	0.10	0.15	0.27	0.17	-0.10
N14	0.80	0.94	0.98	0.91	0.81	0.93	0.97	0.91	0.00

As noted, four of the criteria still had a difference of over 0.2. Thus, it is required to fill in the questionnaires one more round. After sending the difference between expert views and the average responses from the previous stage, they were asked to complete the questionnaires once again. As noted, all the criteria had a difference of less than 0.2. So, it is not

required to fill in the questionnaires once again. This indicates the consensus of the expert views. Table 7 shows the average difference between the experts' second and third-round views. After collecting the third-round questionnaires and calculating the high consensus of the experts over the criteria, it was determined that all the cases with scores of less than 0.7 were removed from the indicators upon receiving feedback from the experts (the removed cases are in red), with the remaining cases selected as the final indicators. In the end, the number of study indicators was 27.

3.2. Extracting the importance of the criteria using the BWM

To determine the indicators' weights, the study first converted them into a hierarchical structure. Then, the importance of the indicators was calculated for each level. In the end, the weights were combined to determine the final weights of the indicators at various levels. Later, these stages were examined. In this section, five experts who were more willing to cooperate and were in a better working position were selected. For this purpose, the weights of the first-level indicators were first calculated, and the findings are presented as follows (Tables 8-10).

Table 8: Results of the first expert views (the best criterion) for the second-level criteria.

Best criterion	E	S	N
E	1	3	9
E	1	7	9
E	1	6	9
S	6	1	9
N	2	9	1

Table 9: Results of the first expert views (the worst criterion) for the second-level criteria.

Worst criterion	N	N	N	N	S
E	9	9	9	2	5
S	4	2	2	9	1
N	1	1	1	1	9

Table 10: Main criteria and their relevant weights.

Main criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
E	0.6857	0.7963	0.7813	0.1354	0.3167	0.5431
S	0.2429	0.1204	0.1354	0.7813	0.0667	0.2693
N	0.0714	0.0833	0.0833	0.0833	0.6167	0.1876
Inconsistency coefficient	0.0429	0.0463	0.0313	0.0313	0.0167	0.0337

Next, for the sub-criteria of each main criterion, this process was repeated and the relevant weight of each sub-criterion was determined. The results for the economic indicators are presented in Table 11.

Social indicator results are presented in Table 12.

The results of the environmental indicator are as Table 13.

So far, the weights of the main criteria and their sub-criteria were extracted. Now, to calculate the final weights of study sub-criteria, their main weights must be multiplied by their sub-criteria to calculate the final weights of each sub-criterion. For this, the following table is given to calculate the final weights of the sub-criteria. Then, using these weights, the ranking process by TOPSIS was performed (Table 14).

Table 11: Secondary criteria of the economic indicator and their related weights.

Main criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
E1	0.1860	0.3061	0.0489	0.1971	0.2977	0.2072
E2	0.3073	0.0487	0.0652	0.0986	0.1980	0.1435
E3	0.0660	0.0557	0.0979	0.2999	0.1320	0.1303
E4	0.0566	0.0649	0.3036	0.0657	0.0990	0.1180
E5	0.0495	0.1948	0.1957	0.0493	0.0660	0.1111
E6	0.1321	0.1299	0.1305	0.1314	0.0792	0.1206
E7	0.0243	0.0974	0.0240	0.0788	0.0495	0.0548
E8	0.0990	0.0247	0.0783	0.0563	0.0566	0.0630
E9	0.0792	0.0779	0.0559	0.0229	0.0222	0.0516
Inconsistency coefficient	0.0889	0.0835	0.0879	0.0943	0.0982	0.0906

Table 12: Secondary criteria of the social indicator and their related weights.

Main criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
S1	0.1980	0.2071	0.1862	0.1948	0.1379	0.1848
S2	0.0990	0.1402	0.3068	0.0974	0.1379	0.1562
S3	0.1320	0.1513	0.0496	0.0649	0.3309	0.1457
S4	0.0222	0.0223	0.0566	0.0487	0.0591	0.0418
S5	0.0792	0.0605	0.1322	0.1299	0.0517	0.0907
S6	0.0566	0.0504	0.0991	0.0779	0.0276	0.0623
S7	0.0660	0.0605	00661	0.0557	0.1034	0.0703

S8	0.0495	0.0336	0.0241	0.0247	0.0829	0.0429
S9	0.2977	0.2740	0.0793	0.3061	0.0689	0.2052
Inconsistency coefficient	0.0982	0.0956	0.0896	0.0835	0.0827	0.0899

Table 13: Secondary criteria of the environmental indicator and their related weights.

Main criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Average
N1	0.3080	0.0776	0.0563	0.1306	0.1660	0.1477
N2	0.1294	0.0544	0.0493	0.1959	0.3144	0.1489
N3	0.0544	0.0253	0.2955	0.0490	0.1354	0.1125
N4	0.0776	0.1941	0.1972	0.3032	0.0508	0.1646
N5	0.0970	0.1294	0.1314	0.0979	0.0580	0.028
N6	0.0647	0.0485	0.0657	0.0653	0.0247	0.0538
N7	0.1941	0.0970	0.0251	0.0238	0.0677	0.0815
N8	0.0485	0.3080	0.0985	0.0784	0.0813	0.1229
N9	0.0253	0.0647	0.0789	0.0560	0.1016	0.0653
Inconsistency coefficient	0.0802	0.0802	0.0968	0.0886	0.0919	0.0875

Table 14: Final weight of the study sub-criteria.

Indicators	Sub-criteria	First level weight	Second level weight	Final weight
Economic	Costs/ prices	0.5431	0.2072	0.1125
	Quality	0.5431	0.1435	0.0780
	Delivery	0.5431	0.1303	0.0708
	Resilience	0.5431	0.1180	0.0641
	Technological capability	0.5431	0.1111	0.0603
	Financial ability	0.5431	0.1206	0.0655
	Participation relations	0.5431	0.0548	0.0298
	Adaptation with strategic sectoral pricing	0.5431	0.0630	0.0342
	Purchase of environmentally friendly materials	0.5431	0.0516	0.0280
Social	Fame/prestige	0.2693	0.1848	0.0498
	Safety and health at the working place	0.2693	0.1562	0.0421
	Employee pay	0.2693	0.1457	0.0392
	Local community influence	0.2693	0.0418	0.0113
	Employee training	0.2693	0.0907	0.0244
	Respect for tights and policies	0.2693	0.0623	0.0168
	Information disclosure	0.2693	0.0703	0.0189
	Reliability	0.2693	0.0429	0.0116
	Technical assistance and support	0.2693	0.2052	0.0553
Environmental	Green image	0.1876	0.1477	0.0277
	Environment protection management system	0.1876	0.1489	0.0279
	Pollution control	0.1876	0.1125	0.0211
	Green products	0.1876	0.1646	0.0309
	design ECO	0.1876	0.1028	0.0193
	Resource consumption	0.1876	0.0538	0.0101
	Using harmful/detrimental substances	0.1876	0.0815	0.0153
	ISO 14001	0.1876	0.1229	0.0231
	Green packaging	0.1876	0.0653	0.0122

3.3. Ranking Using the Fuzzy TOPSIS

The TOPSIS method is one of the multi-criteria decision-making techniques. In this method, there are several options and several criteria for decision-making, with the options ranked based on the criteria or assigned an efficacy score. To calculate the scores in the TOPSIS method, the following is performed: the options should be as close to the positive ideal option as possible, and as distant from the negative ideal option as possible. Thus, one single score is calculated for each option and the options are ranked based on these scores. In this study, the options were Dimas Sazan Jonoub Company (Supplier 1), Arg Band Bana Company (Supplier 2), Mahan Sazaeh Arvand Company (Supplier 3), Masaleh Novin of Khuzestan Company (Supplier 4), and Barname Rizan Abzar Company (Supplier 5), respectively.

The criteria are also given in Table 5. Later, the TOPSIS calculation method is provided.

Stage one is the preparation of a decision-making matrix. In this stage, non-numerical indicators and verbal statements should be converted into numerical values, and it is necessary to focus on the positive and negative aspects of the indicators. Note if verbal variables of the negative criteria (e.g., the difficulty of the task) are reversely transferred (e.g., lower scores are assigned to more difficult tasks). After being transferred, the indicators were converted into direct or positive indicators, i.e., the more the numerical values, the more favorable the options. The table below gives all-positive indicators. The final ranking of the five candidate suppliers was conducted using Fuzzy TOPSIS to handle the inherent uncertainty in performance evaluations. The localized weights derived from the BWM phase were integrated into the fuzzy decision matrix. To ensure the robustness of the ranking, a closeness coefficient (CLi) was calculated for each supplier, representing their relative proximity to the Fuzzy Positive Ideal Solution (FPIS) (Table 15).

Table 15: TOPSIS decision-making matrix.

Type of criterion	Negative	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
	E1	E2	E3	E4	E5	E6	E7	E8	E9
A1-D1	F	G	P	MP	VP	MG	VP	G	MG
A1-D2	MG	MG	MP	P	P	MG	VP	MG	G
A1-D3	F	G	P	P	P	MG	F	MG	MG
A1-D4	MG	MG	MP	P	VP	G	VP	F	MG
A1-D5	F	G	P	MP	P	MG	VP	MG	MG
A2-D1	P	F	VG	G	MP	VG	F	VP	G
A2-D2	P	P	VG	VG	F	G	F	VP	G
A2-D3	VP	F	G	G	MP	VG	MP	VP	MG
A2-D4	P	MP	VG	VG	F	VG	F	VP	G
A2-D5	VP	F	G	VG	F	VG	MP	VP	G
A3-D1	F	VP	F	G	G	F	G	F	VP
A3-D2	MP	P	F	G	MG	F	MG	MG	VP
A3-D3	F	VP	MP	MG	G	MP	G	MG	VP
A3-D4	MP	P	F	G	G	F	G	F	VP
A3-D5	F	VP	MP	G	G	MP	G	MG	VP
A4-D1	G	F	VP	F	MG	G	G	G	MG
A4-D2	VG	G	VP	MP	G	MG	MG	G	G
A4-D3	MG	F	VP	F	G	MG	F	MG	G
A4-D4	G	G	VP	MP	MG	G	MG	G	G
A4-D5	VG	MP	VP	F	G	G	MG	G	G
A5-D1	G	P	F	VP	P	MG	VG	G	MG
A5-D2	MG	MP	F	VP	VP	MG	G	MG	MG
A5-D3	G	P	MP	VP	P	G	VG	G	G
A5-D4	MG	MP	F	VP	P	MG	G	MG	MG
A5-D5	G	P	F	VP	P	MG	VG	MG	G

Type of criterion	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
	S1	S2	S3	S4	S5	S6	S7	S8	S9
A1-D1	VP	G	VP	MG	MG	MG	VG	MG	G
A1-D2	P	MG	P	G	F	MG	VG	G	G
A1-D3	VP	G	P	MG	MG	G	F	G	G
A1-D4	P	G	VP	MG	MG	MG	VG	VG	MG
A1-D5	P	MG	P	G	G	MG	VG	G	G
A2-D1	VP	P	F	P	F	VG	MG	F	G
A2-D2	P	P	F	VP	MP	G	G	F	MG
A2-D3	P	VP	F	P	F	VG	G	F	G
A2-D4	VP	P	MP	P	MP	G	MG	MP	G
A2-D5	P	P	F	P	F	VG	G	F	G
A3-D1	G	MP	MP	VP	MG	G	MP	MP	MG
A3-D2	MG	F	MG	P	G	MG	F	F	G
A3-D3	G	F	F	P	G	G	MP	MP	MG
A3-D4	MG	F	MG	VP	G	MG	F	F	MG
A3-D5	G	MP	MG	P	MG	G	F	MP	MG
A4-D1	VP	F	P	MG	G	MG	G	MG	VG
A4-D2	VP	F	MP	MG	G	MG	G	MG	G
A4-D3	F	MP	F	MG	MG	G	VG	G	VG
A4-D4	VP	F	MP	F	G	MG	G	MG	VG
A4-D5	VP	F	P	MG	G	MG	G	MG	VG
A5-D1	MP	VP	VP	F	MG	MP	MG	P	F
A5-D2	F	P	P	F	MG	F	F	MP	F
A5-D3	F	VP	VP	MP	G	F	MG	P	MP
A5-D4	MP	P	P	F	MG	MP	F	MP	F
A5-D5	F	VP	P	F	MG	F	MG	P	MP

Type of criterion	Positive	Positive	Positive	Positive	Positive	Negative	Negative	Positive	Positive
	N1	N2	N3	N4	N5	N6	N7	N8	N9
A1-D1	VP	MG	VG	VP	VP	P	MG	F	F
A1-D2	P	MG	G	P	P	P	F	MG	F
A1-D3	VP	G	VG	P	VP	P	MG	MG	F
A1-D4	P	MG	VG	VP	P	VP	F	MG	MP
A1-D5	P	G	VG	P	P	P	MG	MG	F
A2-D1	MG	MG	G	G	G	P	VP	F	MG
A2-D2	MG	MG	G	MG	MG	P	P	F	MG
A2-D3	G	G	G	MG	G	MP	VP	MP	MG

A2-D4	MG	MG	MG	MG	G	F	P	F	F
A2-D5	MG	MG	G	G	G	MP	P	F	MG
A3-D1	G	P	G	G	F	F	F	VG	VG
A3-D2	MG	P	G	MG	MP	MP	F	G	VG
A3-D3	MG	VP	MG	G	F	F	MP	VG	VG
A3-D4	G	P	G	G	MP	MP	F	G	G
A3-D5	MG	P	G	G	F	F	F	VG	VG
A4-D1	F	P	G	F	MP	P	MP	F	MG
A4-D2	MP	VP	MG	MP	F	P	P	MG	MG
A4-D3	F	P	MG	F	MP	G	MP	F	F
A4-D4	MP	P	F	MP	F	P	P	MG	MG
A4-D5	F	VP	MG	F	F	P	MP	MG	MG
A5-D1	MG	F	VG	MG	MG	F	MG	VP	G
A5-D2	MG	F	VG	G	F	MG	F	P	VG
A5-D3	F	MP	F	MG	MG	MG	MG	P	G
A5-D4	MG	F	VG	F	MG	F	MG	VP	VG
A5-D5	MG	MP	VG	MG	MG	MG	MG	P	VG

In the second stage, the decision-making (D) matrix is converted into an unscaled decision matrix. The third stage calculates the normal weighted scale. For this, each of the criteria must be assigned a weight. These weights were calculated by the BWM method. Then, by multiplying the weight matrix coefficient by the unscaled matrix, the weighted unscaled matrix was produced. The fourth stage determines hypothetical positive and negative ideal options. For the formation of the positive ideal option (+A), the best value should be selected in each of the V matrix columns. For the formation of the negative ideal option, the reverse of +A was performed, i.e., in each column of the indicators, the lowest value was selected (Table 16).

Table 16: Positive and negative ideals for each criterion.

Type of criterion	**Negative**			**Positive**			**Positive**		
	E1			**E2**			**E3**		
Positive ideal	0.03	0.04	0.11	0.06	0.07	0.08	0.06	0.06	0.07
Negative ideal	0.01	0.01	0.01	0.00	0.01	0.02	0.00	0.01	0.01

Type of criterion	**Positive**			**Positive**			**Positive**		
	E4			E5			E6		
Positive ideal	0.05	0.06	0.06	0.05	0.05	0.06	0.05	0.0.06	0.07
Negative ideal	0.00	0.01	0.01	0.00	0.01	0.02	0.02	0.03	0.04

Type of criterion	**Positive**			**Positive**			**Positive**		
	E7			E8			E9		
Positive ideal	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03
Negative ideal	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01

Type of criterion	**Positive**			**Positive**			**Positive**		
	S1			S2			S3		
Positive ideal	0.04	0.04	0.05	0.03	0.04	0.04	0.02	0.03	0.04
Negative ideal	0.00	0.01	0.02	0.00	0.01	0.01	0.00	0.01	0.01

Type of criterion	**Positive**		**Positive**		**Positive**	
	S4		S5		S6	

Positive ideal	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
Negative ideal	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.0.01

Type of criterion	**Positive**			**Positive**			**Positive**		
	S7			S8			S9		
Positive ideal	0.01	0.02	0.02	0.01	0.01	0.01	0.04	0.05	0.06
Negative ideal	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.02	0.03

Type of criterion	**Positive**			**Positive**			**Positive**		
	N1			N2			N3		
Positive ideal	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02
Negative ideal	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.02

Type of criterion	**Positive**			**Positive**			**Negative**		
	N4			N5			N6		
Positive ideal	0.02	0.03	0.03	0.01	0.02	0.02	0.00	0.00	0.01
Negative ideal	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00

Type of criterion	**Negative**			**Positive**			**Positive**		
	N7			N8			N9		
Positive ideal	0.00	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Negative ideal	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01

In the fifth stage, the distances from each option to the positive and negative ideal options were calculated. For this, the V matrix information was used. The distance of the I option to the positive ideal was represented by +di and to the negative ideal by -di.

Then, as for the score calculation (the ratio of closeness to the ideal option), the ratio of closeness to the ideal option, represented by (CLi), was calculated (Table 17).

Table 17: Final results of the TOPSIS analysis.

Supplier companies	**CLi**	**Final ranking**
Supplier 1	0.42	4
Supplier 2	0.63	1
Supplier 3	0.49	2
Supplier 4	0.46	3
Supplier 5	0.34	5

Finally, the options were ranked according to the CLi value. The higher the value, the more favorable the option. Supplier 2 (Arg Band Bana Co.) achieved the highest rank (CLi=0.63), primarily due to its superior performance in Economic criteria (E1, E2) and Green Competence (N7), which carried the highest weights in the BWM phase. This suggests that for Maskan Bank projects, financial stability coupled with environmental compliance is the decisive factor in supplier selection.

4. Results and Discussion

4.1. Expert Demographic Profile

The demographic characteristics of the 30 experts are presented in Table 4. The panel reflects a relatively mature and highly qualified group, with 70% of respondents being over 40 years old and 80% holding a Master's degree or higher. This profile supports the credibility of the fuzzy judgments and the reliability of the subsequent weighting process.

All participants were male. This composition reflects the current gender distribution in senior technical and managerial positions within the Iranian construction material supply chain. Nevertheless, expert selection was based strictly on predefined merit-based inclusion criteria, including extensive relevant experience and appropriate academic or professional qualifications, rather than demographic characteristics. This limitation should be considered when interpreting the generalizability of the findings.

4.2. Fuzzy Delphi Screening Results and Final Indicator Set

An initial list of sustainability indicators was extracted from the literature and then adapted to the context of construction material procurement. These indicators were screened using the Fuzzy Delphi method. In this process, experts evaluated each indicator using linguistic terms represented by triangular fuzzy numbers, and consensus was assessed iteratively.

The Delphi procedure was continued until the stopping rule was satisfied, namely when the absolute difference between the defuzzified group averages of two consecutive rounds became less than 0.2 for all indicators. This convergence criterion ensured that the final indicator set reflected a stable expert consensus rather than isolated individual opinions.

After screening, the remaining indicators were retained as the final criteria for supplier evaluation. This localization

process is one of the key contributions of the study, as it transforms a broad sustainability concept into a practical indicator set tailored to the procurement realities of construction projects.

4.3. Criteria Weighting Results Using the Best–Worst Method (BWM)

The confirmed criteria were then prioritized using the Best–Worst Method. In this stage, a group of five experts participated in the pairwise comparisons, and the criteria were organized in a hierarchical structure. The best and worst criteria were identified at each level, and the weights were estimated by solving the BWM linear programming formulation.

The results show that the Economic dimension received the highest weight, followed by the Social and Environmental dimensions. This ordering is consistent with the project-based nature of the construction industry, where cost efficiency, timely delivery, and financial feasibility remain the main decision drivers. In practical terms, this suggests that suppliers must first meet economic expectations before sustainability-oriented differentiators can meaningfully influence the final decision.

The BWM consistency results further support the validity of the obtained weights. According to the reported inconsistency coefficient, the average value for the main-criteria comparisons was **0.0337**, which indicates a high level of agreement among experts and strengthens the reliability of the derived priorities.

4.4. Ranking Results Using Fuzzy TOPSIS

The final supplier ranking was obtained through Fuzzy TOPSIS. The local weights derived from BWM were applied to the fuzzy decision matrix, and the distances of each alternative from the Fuzzy Positive Ideal Solution and Fuzzy Negative Ideal Solution were computed. The closeness coefficient, CL_i , was then calculated for each supplier to determine the final ranking.

As reported in Table 17, the suppliers were ranked according to their CL_i values, where a higher value indicates a more favorable alternative. The results show that Supplier 2 achieved the highest closeness coefficient and was therefore ranked first among the alternatives. This indicates that Supplier 2 exhibited the best overall performance relative to the ideal sustainable supplier profile under the proposed weighting scheme.

This result is consistent with the dominance of the economic dimension in the weighting structure. Since economic criteria carried the greatest importance, suppliers with stronger performance in cost, quality, and delivery-related indicators were more likely to obtain a superior overall ranking. At the same time, the ranking outcome also reflects the contribution of social and environmental criteria, which prevented the decision from being based solely on short-term financial considerations.

4.5. Discussion on Sustainability Contribution

A major contribution of this research is the development of a localized and operational framework for sustainable supplier selection in the construction materials supply chain. Rather than treating sustainability as a purely conceptual issue, the study converts it into a structured decision-making process that combines expert judgment, criterion screening, criterion weighting, and supplier ranking.

The findings show that, in the current Iranian construction context, economic factors still dominate procurement decisions. However, the inclusion of social and environmental criteria in the model ensures that supplier selection is not reduced to cost alone. This is especially important for institutions such as Maskan Bank and similar stakeholders that seek to gradually move procurement practices toward more sustainable and accountable models.

In this sense, the study bridges the gap between sustainability theory and procurement practice. It demonstrates that sustainable supplier selection in construction is not an all-or-nothing transition, but a staged decision process in which economic feasibility remains central while social and environmental considerations progressively gain importance.

4.6. Sensitivity Analysis

To evaluate the robustness of the supplier rankings and ensure that the results are not overly sensitive to fluctuations in decision-makers' preferences, a sensitivity analysis was conducted. Given that the 'Economic' criterion emerged as the most significant factor (w=0.5431), three scenarios were tested:

• Scenario 1 (S1): Increasing the weight of the Economic criterion by 10%.

• Scenario 2 (S2): Decreasing the weight of the Economic criterion by 10%.

• Scenario 3 (S3): Assuming equal weights for all three main sustainability pillars (Economic, Social, Environmental).

The results (summarized in Table 18) indicate that while the closeness coefficients (CL_i) exhibited minor fluctuations, the top-ranked supplier (Supplier 2 - Arg Band Bana Co.) remained consistent across all scenarios. This confirms the stability of the proposed framework and the reliability of the final selection for the Maskan Bank projects. (Fig.2)

Table 18: Sensitivity analysis results under main-criteria weight perturbations

Scenario	w(Econ)	w(Soc)	w(Env)	Rank 1	Rank 2	Rank 3–5 (Summary)
Base	0.5431	0.2693	0.1876	S2	S3	S4, S1, S5
S1 (+10%)	0.5974	0.2374	0.1652	S2	S3	S4, S1, S5
S2 (-10%)	0.4888	0.3013	0.2099	S2	S3	S4, S1, S5
S3 (Equal)	0.3333	0.3333	0.3333	S2	S3	S1, S4, S5

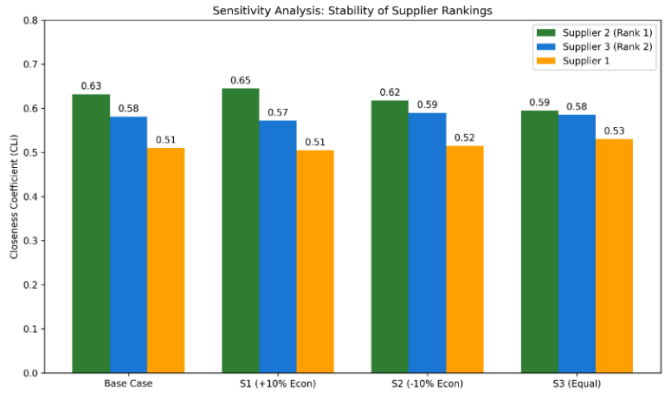


Fig. 2: sensitivity analysis:stability of supplier Ranking

5. Conclusion

This study proposed a hybrid multi-criteria decision-making framework for sustainable supplier selection in construction projects by integrating the Fuzzy Delphi method, the Best–Worst Method (BWM), and Fuzzy TOPSIS. The framework was developed to support supplier evaluation under uncertainty and to provide a structured basis for incorporating sustainability considerations into procurement decisions. Using this approach, a context-specific set of sustainability criteria and sub-criteria was identified and applied to the evaluation of construction material suppliers in Maskan Bank projects.

The findings showed that economic criteria had the highest importance in the decision-making process, followed by social and environmental criteria. This result reflects the practical conditions of the construction industry, where cost, quality, and delivery performance remain critical concerns. At the same time, the inclusion of social and environmental indicators demonstrates the need to move beyond purely cost-based decisions toward a more comprehensive and sustainable supplier selection approach. In this context, the proposed model provides a practical decision-support tool for procurement managers and project stakeholders.

The study also highlighted the relevance of several context-dependent indicators that may appear more common in industrial or electronic supply chains, such as RoHS, WEEE, EUP, and ODC-related considerations. In large-scale construction projects, particularly those involving integrated electrical, mechanical, and smart building systems, such indicators can play an important role in evaluating suppliers of equipment and building components. Their inclusion therefore improves the applicability of the framework to contemporary construction procurement practices.

The ranking results showed that Supplier 2 achieved the highest closeness coefficient and was identified as the most suitable supplier among the evaluated alternatives. In addition, the sensitivity analysis confirmed the stability of the results, as the ranking of the top suppliers remained unchanged under different weighting scenarios, including ±10% changes in the economic dimension. This finding supports the robustness and reliability of the proposed framework.

Overall, this study contributes to the sustainable procurement literature by localizing sustainability criteria for the Iranian construction context and linking them to the operational realities of supplier selection in large construction projects. From a practical perspective, the framework can assist decision-makers in banks, contractors, and procurement departments in making more transparent, balanced, and sustainability-oriented supplier selection decisions. Future research can extend this framework by applying it in other construction sectors, testing it in different geographical and regulatory settings, and involving more diverse expert panels.

5.1. Limitations and Future Research

This study has some limitations that should be acknowledged. First, the expert panel consisted entirely of male participants. This reflects the current structure of leadership and decision-making positions in the regional construction sector; however, it may limit the diversity of perspectives, particularly regarding social sustainability issues. Future studies are encouraged to include more diverse expert panels in order to improve the representativeness of the findings.

Second, the empirical evaluation was conducted based on suppliers associated with Maskan Bank construction projects within a specific regional and organizational context. Therefore, although the proposed framework can be applied in other settings, the relative importance of the criteria and the final ranking of suppliers may differ across geographical regions, institutional environments, and construction subsectors.

Third, due to the specialized nature of the research topic and the limited availability of qualified experts, convenience sampling was used in this study. Although the selected experts had relevant experience and sufficient knowledge in the field, this sampling approach may limit the generalizability of the findings beyond the studied context.

Future research can address these limitations by involving more diverse expert groups, applying the framework across different construction sectors and geographical settings, and examining the effects of changes in market conditions, regulatory requirements, and sustainability policies on supplier evaluation results.

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Conflict of interest

The authors declare that they have no conflict of interest.

Author contribution statement

a, b, c: contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

Data availability statement

Data generated or analysed during this study are provided in full within the published article

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